The Emergence and Development of Cross-National Knowledge Sharing and Production: Case Studies of International Collaborative Projects in South Korea

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The Emergence and Development of Cross-National Knowledge Sharing and Production: Case Studies of International Collaborative Projects in South Korea

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To my grandmother

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LIST OF ABBREVIATIONS

CPS	Country Partnership Strategy
DAC	Development Assistance Committee
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
EU	European Union
GDP	Gross Domestic Product
GNI	Gross National Income
HR	Human Resources
ICES	International Conference on Energy and Sustainability
IRB	Institutional Review Board
KAIST	Korea Advanced Institute of Science and Technology
KIST	Korea Institute of Science and Technology
KOICA	Korea International Cooperation Agency
KOSEF	Korea Science and Engineering Foundation
LDC	Least Developed Country
MOU	Memorandum of Understanding
NSB	National Science Board
NGO	Non-governmental organizations
NNI	National Nanotechnology Initiative
NNISP	National Nanotechnology Initiative Strategic Plan
NRF	National Research Foundation of Korea
NSB	National Science Board

NSF	National Science Foundation
ODA	Official Development Aid
OECD	Organization for Economic Co-operation and Development
PI	Principal Investigator
PM	Project Manager
PV	Photovoltaic
R&D	Research and Development
S&T	Science and Technology
STEPI	Science and Technology Policy Institute
TEDAP	Tanzania Energy Development and Access Project
TPC	Techno Peace Corps
VAT	Value Added Tax (VAT)

SUMMARY

Highlighting South Korea's transition from a recipient of official development aid (ODA) to a donor country in 2010, this study examined two cases of cross-national knowledge sharing and production in South Korea: one with the US and the other with Tanzania. Previous studies regarding university research collaboration have explored various issues, such as collaborative university-industry-government networks, macro-level and structural factors affecting research collaboration, micro-level and individual factors influencing the collaboration, and the cultural and ethical issues for the various types of collaborations. However, a more in-depth engagement of both structure and agency in cross-national knowledge sharing and production in countries that have recently transitioned from recipients to donors of ODA, such as South Korea, remains an area for fruitful exploration. The examination of case studies of international academic research collaboration projects in South Korea with U.S. and Tanzanian partners in this dissertation fills this gap, shedding new insight into how bridging countries, such as South Korea, negotiate scientific knowledge sharing and production processes.

The objective of this study was to understand the structure-agency relationship in cross-national university research collaboration in a country that has made the transition of becoming a donor of developmental aid. The case studies of international academic research collaboration projects in South Korea with U.S. and Tanzanian partners examine the contributions of actors from a bridge country (South Korea) and its partners from developed (US) and developing (Tanzania) countries, where science and technology (S&T) have developed unevenly. Using qualitative methodologies, including ethnography, participant observation, and semi-structured interviews, from January 2018

to February 2019, I conducted fieldwork in a mechanical engineering laboratory in South Korea that is collaborating with the US and Tanzania.

Theoretically, this study investigated the relationship between structure and agency with Bourdieu's concepts of symbolic power and *habitus*. According to Bourdieu, symbolic powers, such as economic, social, and cultural capital, limit individual activities within society, while individuals influence social structures through habitus. The analyses of two South Korean collaborative university research projects that have been conducted in conjunction with U.S. and Tanzanian universities showed that actors from a bridge country (South Korea) contributed to cross-national knowledge sharing and production by balancing structural discrepancies through different forms of agency. The findings of this study suggest that economic, social, and cultural capital simultaneously promotes and hampers cross-national knowledge sharing and production among developed, developing, and bridging countries. In addition, while social structure influenced the behaviors and minds of participants engaging in joint research projects, individual agency motivated the projects and offered flexibility and opportunities for cross-national knowledge sharing and production.

CHAPTER 1. INTRODUCTION

In 2010, South Korea made the rare transition from being a recipient to a donor country of official development aid (ODA).[1] By taking this step, South Korea (hereafter referred to Korea or Korean) joined a group of donor countries in the Development Assistance Committee (DAC) of the Organization for Economic Co-operation and Development (OECD; Choi 2011). Although the history of Korean ODA traces back to the 1960s, when the Korean economy began to recover from the Korean War (1950–1953), joining the OECD in 1996 and subsequently the DAC in 2010 officially made Korea one of the world's donor countries (OECD 2008, Marx and Soars 2013).

The economic growth of Korea during the postwar period and the transition of Korea to becoming a donor of ODA are closely related. In its special review of Korea's development cooperation, OECD (2008) claimed that the effective use of ODA has partially contributed to the growth of the Korean economy after the war.[2] Accordingly, in 2010, one of the Korean government's rationales for becoming a donor of ODA was to repay its historical debts to the world (Kim 2011). This humanitarian rhetoric of the Korean government has not been fully achieved because the Korean government has spent more on tied rather than untied grants. However, the gap between the government's rhetoric and the way how the Korean government spends its ODA budgets does not

[1]According to OECD (2003), ODA refers "flows of official financing administered with the promotion of the economic development and welfare of developing countries as the main objective" (See OECD Glossary of Statistical Terms available at https://stats.oecd.org/glossary/detail.asp?ID=6043).
[2]According to OECD (2008), the Korean government received approximately 12.7 billion USD during the post-war period in order to develop national economy and decrease poverty.

diminish the fact that sustainable growth after the war has led Korea to become a donor of ODA (Kim 2011, Marx and Soars 2013).

The transition from a recipient to a donor country of ODA is relatively uncommon. Amongst 30 donors, including 29 countries and an institution (the European Union) listed on the DAC of OECD, only three countries, Greece, Korea, and Portugal, have transitioned from being a recipient of ODA to a donor country.[3] In addition, as of 2019, out of the 15 largest donors in the DAC, Korea is the only country to have made such a transition.[4] The volume of Korean ODA has gradually increased since the transition occurred. According to the Export Import Bank of Korea, the Korean government distributed 1.17 billion USD in 2010 and 2.5 billion USD in 2019 through ODA grants.[5] With regard to this unusual change, studies that have highlighted Korea's journey from being a recipient of ODA to becoming donor have suggested that Korea take on a new role as a "bridge" between countries with various levels of development (Kim et al. 2013; Kalinowski and Cho 2012; Mawdsley 2012; Choi 2011). Here, a bridge country denotes a country that possesses the capability of sharing the experience of transition. That is, Korea's transition created a new role for it to fulfill in the field of global development.

After the transition, cross-national knowledge sharing and production stood out as a potential endeavor for Korea in its new role as a bridge country. In 2011, the Korean government decided to share its developmental experience in science and technology

[3]See http://www.oecd.org/development/financing-sustainable-development/development-finance-standards/historyofdaclistsofaidrecipientcountries.htm#Chronology
[4]See https://donortracker.org/, also see https://www.oecd.org/dac/development-assistance-committee/ for the list of DAC donors
[5]See https://stats.koreaexim.go.kr/odastats.html

(S&T) with other countries and included technology sharing in its key agenda for the development of national S&T. In line with the changes in the developmental status of Korea, the objective of this study is to understand the structure-agency relationship in cross-national S&T collaboration in a country that has made this unusual transition to becoming a donor of development aid. In particular, this study mainly answers the following questions: What is the power dynamic amongst developed, developing, and bridging countries in the production of collaborative S&T knowledge? How do actors in a bridge country (Korea) contribute to this cross-national knowledge sharing and production?

One aspect of knowledge sharing and production is university research collaboration, studies of which have examined various issues, such as collaborative networks of university-industry-government, macro-level and structural factors affecting research collaboration, micro-level and individual factors influencing collaboration, and cultural and ethical issues for various types of collaborations. In addition, relevant studies have revealed important processes, facilitators, and barriers to cross-national knowledge sharing and production in the context of university research collaborations.

Because the context of transition provides different structures for actors, this study contributes to the advance of literature regarding cross-national university collaborations and development.[6] Even though Korea was one of the 15th largest donors of ODA in terms of the total volume in 2019, the three countries that have undergone the transition from recipient to donor are still considered small donors when ODA to gross

[6]For example, the volume of ODA in universities has increased from 0.48 million USD in 2009 to 1.35 million USD in 2010, and 7.9 million USD in 2018 in Korea. See https://stats.koreaexim.go.kr/odastats.html

national income (GNI) ratio is taken into account.[7] For example, Korea ranked 25th for its ODA to GNI ratio among DAC member countries (OECD 2020). Thus, findings from this study imply how researchers in one of these small and recently transitioned donor countries position their cross-national knowledge sharing and production within the context of global development. Moreover, focusing on actors in a transitioned country contributes to effectively designing bilateral and multilateral collaborative projects between countries with various developmental statuses.

To analyze the structure-agency relationship in cross-national university knowledge sharing and production in a transitioned country, this study examines two cases of cross-national research collaboration in a Korean national university: one with the United States (US) and the other with Tanzania. The case studies of international academic research collaboration projects in Korea with U.S. and Tanzanian partners examine the contributions of actors from a bridge country (Korea) and its partners from developed (US) and developing (Tanzania) countries, where science and technology (S&T) have developed unevenly. Between 2017 and 2020, a mechanical engineering research team in a Korean national university conducted two international collaborative projects that reflect the current status of Korea as a bridge country between developed and developing countries. That is, the Korean mechanical engineering team in this study conducted one project with a U.S. university and another with a Tanzanian university.

Using qualitative methodologies, including ethnography, participant observation, and semi-structured interviews, this project investigates these two cross-national research

[7]In 2019, Korea granted 2.5 billion USD (0.15% of GNI), Portugal granted USD 373 million (0.16% of GNI), and Greece granted USD 308 million (0.14% of GNI) for ODA (OECD 2020).

projects. From January 2018 to February 2019, I conducted fieldwork in a mechanical engineering laboratory in Korea that is collaborating with the US and Tanzania. I visited Tanzanian and U.S. laboratories for one month and two months, respectively. Additionally, I studied each joint project through participant observation in the laboratory and in-depth interviews with principal investigators (PIs) and students. By identifying the national and individual contexts that affect the international research collaboration projects from the bottom up, this study reveals the relationship between embedded structures and individual agency in the process of cross-national research collaboration at a Korean national university.

Theoretically, this study investigates the relationship between structure and agency with Bourdieu's concepts of symbolic power and *habitus*. According to Bourdieu, symbolic powers, such as economic, social, and cultural capital, limit individual activities within society, while individuals influence social structures through habitus. Here, economic capital refers to material assets that are convertible into money, social capital refers resources that are connected to relationships, and cultural capital indicates values, skills, knowledge, and tastes that are embodied in people; habitus is defined as a social space generated historically through interactions of objective probabilities (structure) and subject aspirations (agency; Bourdieu 1986). Bourdieu's notions of symbolic power and habitus suggest that social structures determine individual or group agency through symbolic powers, while individual agents influence social structures through habitus.

To study international collaborative projects in Korea with countries of varying degrees of development, this study uses Bozeman and Boardman's (2014) definition of research collaboration. Bozeman and Boardman (2014:2) define collaboration as "social

processes whereby human beings pool their experience, knowledge, and social skills with the objective of producing new knowledge, including knowledge as embedded in technology." With this broader definition, the authors distinguished between "knowledge-based" and "property-based" collaborations. According to the authors, knowledge-based collaboration aims at producing knowledge, such as journal articles, while property-based collaboration aims at generating wealth, such as new businesses and profits.

In this study, a joint research project between the Korean and U.S. teams focuses on the development of computational modeling and an end product of a nanoparticle deposition system. Even though the goal of the project was to invent a relevant computational model and machine, the requirement of the project's funding agencies, the Brain Korea 21 Plus project of the National Research Foundation of Korea (NRF) and the National Science Foundation (NSF), was to publish journal articles during the project period. Therefore, this mainly constituted a "knowledge-based" collaboration.

In contrast, the joint research project with a Tanzanian university centered on the implementation of power transmission grids in rural areas for the distribution of solar energy. While publication of articles is one of the goals for the collaboration between the Korean and Tanzanian teams, the collaboration mostly focuses on creating new businesses using solar energy and sustaining a local appropriate technology center. Thus, the joint project between Korean and Tanzanian team can be considered more of a property-based collaboration than a knowledge-based collaboration.[8]

[8]As for the joint project between Korea and Tanzania, the requirements from NRF Korea were to implement a joint research center related to solar energy in a Tanzanian local university. The topics of sub-projects that were conducted by the joint center, such as the

Despite an effort to distinguish two projects, however, this study shows that the boundary between knowledge-based and property-based collaboration is vague and both types of collaboration are intertwined in each project. For example, the joint project between the U.S. and Korean team was not purely knowledge-based, as it pursued the development of computational models and relevant devices. In addition, the joint project between Tanzanian and Korean teams sought to publish journal articles while producing relevant products. Therefore, this study suggests that the process of knowledge sharing and production does not necessarily fit into a single category of Bozeman and Boardman's proposed demarcation. While knowledge-based collaboration may involve the process of production, property-based collaboration may also involve the process of publication.

Following this introduction, Chapter 2 explores previous studies and this project's research design. After introducing relevant literature and the research design of this study, Chapters 3 and 4 explain the national and technological background for the case studies. In particular, Chapter 3 discusses the technological, economic, educational, and political contexts of the three countries: Korea, Tanzania, and the US. Chapter 4 examines the history of technology studied in both collaborative projects and the emergence of cross-national collaborative projects for the Korean team. Later, in Chapter 5, I analyze how structure and agency are related in a country serving as a bridge between developed and developing countries. Finally, this dissertation concludes with the study's main arguments, contributions, limitations, and recommendations for future studies.

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implementation of power-transmission grids in rural Tanzania, were proposed by the research team. For NRF, the aim of the Brain Korea 21 project was to support a doctoral student and the aim of the joint project between Tanzania and Korea was to support a joint research center including both direct and indirect (overhead) costs.

CHAPTER 2. LITERATURE REVIEW AND RESEARCH DESIGN

2-1. Literature Review

2-1-1. University research collaboration

The growing number of internationally coauthored journal articles implies that cross-national university collaboration has become a growing trend worldwide (Bozeman and Boardman 2014; Bozeman and Youtie 2018; NSB 2018). Between 2006 and 2016, the National Science Board (NSB) in the US (2018) indicates that the internationally coauthored publications in U.S. universities increased from 24.9% to 37.2%. According to the NSB (2018), the increase of university research collaboration within or among countries with various degrees of development resulted from national initiatives, technological development, and risk-sharing opportunities. That is, government policies driven by the knowledge economy, technologies that facilitate cross-national communications, and possibilities that share the risk of investing in innovative research and development (R&D) encouraged international university-university collaborations.

Previous studies regarding university research collaboration have examined the following issues in countries with various degrees of development: collaborative networks of university-industry-government, macro-level and structural factors affecting research collaboration, micro-level and individual factors influencing collaboration, and cultural and ethical issues regarding various types of collaborations. As far as the collaborative networks among various types of organizations, such as universities, industries, and government agencies, are concerned, the most recent studies have suggested that collaborations among universities, industries, and government (also referred as the triple helix model) are essential for S&T innovation (Leydesdorff 2018;

Etzkowitz 2019; Borek et al. 2020). In particular, Etzkowitz (2019) argued that using polyvalent knowledge produced in universities as the seeds of innovation, universities have evolved to become a key actor for transforming knowledge into use, while governments have served as financial supporters and industries have acted as users of knowledge.

The triple helix model suggests that different organizational actors contribute to S&T innovation. According to Etzkowitz and Leydesdorff (2000:111), the shape of tri-lateral cooperation among three sectors—university, industry, and government—has evolved in the following three phases:

- *Triple Helix I:* The nation-state encompasses academia and industry and directs the relations between them.
- *Triple Helix II*: Separate institutional spheres with strong borders and highly circumscribed relations among the spheres.
- *Triple Helix III:* Overlapping institutional spheres with each taking the role of the other and with hybrid organizations emerging at the interfaces.

The above phases address various transitions in the relationship amongst the three organizational actors engaging in S&T innovation. The role of government is stronger in the first phase than in the second and final phases. While the second phase involves compartmental roles for each actor, the final phase indicates weak boundaries among the three actors.

Using co-patent data and the triple helix model, Yoon (2015) suggested that Korean universities have transitioned into leading actors in the triadic collaboration of university-industry-government since 2001. According to Yoon (2015), in transforming

universities into key actors, the Korean government tripled their budget for academic research from 894 million USD to 3.4 billion USD between 2002 and 2012. The strength of the triple helix model is that it conceptualizes the evolution of organizational actors and their collaboration for national innovation. However, focusing on the balance among industrial, academic, and government actors for the achievement of national innovation, the triple helix model failed to entail the role of other actors, such as individuals or regional environment. Accordingly, other studies have profiled actors such as consumers, users, non-governmental organizations (NGO), and community (Ivanova 2014; Lindberg et al. 2014; Miller et al. 2018; Doh 2018). For instance, Doh (2018) argued that the triple helix frame must incorporate community as another actor because generally, industrial activities in developing countries are informal and community-based. By including community as another actor, Doh (2018) addressed the role of individuals with local knowledge, microbusiness owners, and local officials who participate in local community innovations.

Another weakness of the triple helix model is that it does not engage with the cross-national aspect of innovation processes. According to Cai and Etzkowitz (2020), despite the increase of cross-national innovation, the conventional model of the triple helix does not reflect the sphere of globalization. In particular, based on their study on European Union (EU)-China cooperation, Cai et al. (2019) claimed that an advanced model of triple helix innovation needs to incorporate the value of cross-national university collaboration. For example, in the case of S&T innovative collaboration between the EU and China, existing connections between European and Chinese universities enhanced the outcome of cross-national innovation by optimally matching

industrial firms from each country (Cai et al. 2019). In other words, the social connections between European and Chinese universities helped build trustworthy relationships between other actors. Acknowledging the lack of cross-national views in the conventional triple helix model, Cai et al. (2019) incorporated the diagram of transnational space in their new model.

In addition to not engaging various actors and cross-national aspects, Cai and Etzkowitz (2020) asserted that the triple helix model does not sufficiently explain the links between macro- and micro-level actors. For example, arguing that various forms of capital are combined in the process of national innovation in India, Datta and Saad (2011) suggested the incorporating theories of economic, human, social, and cultural capital into the triple helix model. In this study, the joint project between Tanzania and Korea exemplified the process of knowledge sharing and production framed by the triple helix model. For example, the joint project includes all three actors (university, government, and industry), and universities serve as the leading actor in the process of cross-national knowledge sharing and production. However, using Bourdieu's concept of structure and agency, this study not only further demonstrates actors missing in the triple helix model, such as the economy, social networks, culture, and individuals, but also shows how macro- and micro-level actors are engaged in the process of cross-national knowledge sharing and production.

Studies pertaining to the effectiveness of research collaboration have also examined other structural factors. That is, relevant studies suggest that high communication costs resulting from physical, linguistic, and institutional distances among researchers hinder collaborations (Ponomariov and Boardman 2010; Kalawong

2016; Bozeman and Youtie 2018). Using a case study of a network of six universities located in Thailand, Vietnam, Malaysia, and Indonesia, Kalawong (2016) claimed that dissimilar bureaucratic systems and languages hinder international academic collaborations.

As methods of reducing structural barriers and increasing the effectiveness of research collaboration, Ponomariov and Boardman (2010) suggested that university research centers reduce transaction costs and increase the productivity of research collaborations. In addition, Bozeman and Youtie (2017:126-127) claimed that when conflicts among actors hinder effective collaboration, institutional resources, such as "ethics codes, training programs, review boards, and journal requirements," raise the effectiveness of research collaboration by resolving conflicts. The strength of previous studies regarding the effectiveness of national and international research collaboration is that they discuss embedded structures of research collaboration. However, structural approaches do not show the role of micro-level actors engaged in international research collaborations.

In contrast to studies focused on structural factors, Wang (2016) identified individual-level influences on research collaborations. To articulate the impact of the size and the strength of an individual's collaborative network on the quality of his or her research, Wang (2016) examined the relationship between the total number of citations, the number of coauthors, and the frequency of collaboration during a five-year period between 1980 and 2009. In this study, the total number of citations referred to the usefulness of scientific knowledge, the number of coauthors indicated the size of collaborative networks, and the frequency of collaboration referred to the strength of the

collaborative networks. Analyzing panel data from 1,042 U.S. academic scientists in the fields of biology, chemistry, computer science, earth and atmospheric sciences, electrical engineering, and physics, Wang (2016) showed that the number of citations increased as the size of the network increased to 58 coauthors. After that threshold, the number of citations decreased because the increase in collaborators resulted in the production of redundant ideas from collaborators who are similar to each other. Similarly, frequent collaboration increased the number of citations at first, but later, it hindered the quality of research. Even though this study was limited to the selected fields, the author revealed individual-level influences on research collaborations.

As for individual-level influences on cross-national research collaboration, studies pertaining to science and technology human capital (STHC) model also suggested that individual researchers' financial, social, and cultural resources affect the productivity of research collaboration (Bozeman and Boardman 2014; Lawson and Shibayama 2015; Corley et al. 2019). According to Bozeman et al. (2001:636), STHC is defined as "the sum of an individual researcher's professional network ties, technical knowledge and skills, and resources broadly defined." While Bozeman et al.'s conventional STHC model identified individual researchers' human and social capital as a parameter of the research productivity, Corely et al. (2019) claimed that the model needs to incorporate the node of cultural capital because diverse cultural experiences of individual researchers influence the productivity of research collaboration. In line with Wang (2016)'s study on the impact of individual networks on scientific collaboration, studies regarding the STHC model show how individual researchers impact the structure of cross-national research collaboration.

The summaries and a proceeding of workshops on international research collaboration organized by National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine (National Academies) in the US addresses the direct engagement between S&T policies and individual actors (NAS 2011; NAS 2014; NAS 2018). Complementing studies pertaining to obstacles to domestic and international academic collaborations, these summaries and the proceeding stressed the importance of cultural and ethical issues regarding university collaborations across national boundaries (NAS 2011; NAS 2014; NAS 2018). During the workshop, domestic and international experts on international research collaborations discussed relevant issues such as cultural differences, research ethics, risk management, intellectual property, and export controls. By identifying cultural and ethical issues in cross-national university collaborations at the ground level, the summaries and the proceeding shows how individual actors and structural policies interact. In other words, according to these workshops, micro-level actors suggest policies that influence collaborative activities.

The summary of the workshop in 2011 included the perspective of Tembeka Mpako-Ntusi, a director of research at the Cape Peninsula University of Technology (CPUT) in Cape Town, South Africa. Mpako-Ntusi said, “In the case of South Africa, the historical issues of race, past intimidation, and power imbalances play a role” (NAS 2011:23). That is, a national context can influence the relationship between collaborative partners. According to Koehn and Obama (2014), even though international university-university collaborations between the North (mainly in Europe and North America) and South (mainly in sub-Saharan Africa) have pursued equal relationships between partners by sharing the recognition and outputs of collaborative projects, in reality, achieving an

equal relationship is difficult for cross-national collaborations between developed and developing countries. Illustrating the relevance between structures (i.e., S&T policies and historical issues) and agency (i.e., individual participants in a workshop), the summaries and the proceeding of the workshops offer an abstraction of the macro or structural forces and the micro or individual experience.

This section of the dissertation investigated previous studies pertaining to academic research collaborations. The previous studies have focused on the collaborative networks of university, industry, and government, structural factors influencing research collaboration, and individuals' influence on research collaboration. In addition, the summaries and the proceeding of NAS workshops suggested that cultural and ethical issues prevail in international academic research collaboration between developed and developing countries. While previous studies have shown either macro-level structure or micro-level agency, or the abstraction of macro- and micro-level issues relevant to university collaborations, more in-depth engagement of both structure and agency in cross-national knowledge sharing and production in countries that have recently transitioned from recipients to donors of official development aid, such as Korea, remains an area for fruitful exploration. Investigating international collaborative projects in a Korean university with universities in the US and Tanzania, my case studies focus on the structure-agency relationship in cross-national knowledge sharing and production in a bridge country that has recently transitioned from recipient to donor of official development aid.

2-1-2. Bourdieu's concept of symbolic power and habitus

To examine the structure-agency relationship in two cases of cross-national research collaboration in a Korean national university, I conceptualize the relationship between structure and agency. However, conceptualizing the relationship between structure and agency is difficult because focusing on either one may possibly lead to ignoring the other. By situating micro-level academic research collaboration in broader social contexts, such as national and institutional structures, this study investigates the relationship between structure and agency using Bourdieu's concepts of symbolic power and habitus.

Bourdieu focuses on eight social problems connected to the relationship between structure and agency. He defines structure as objectivism and agency as subjectivism, and efforts to connect them allow Bourdieu to address both agency and constraints within society. In particular, the eight social problems Bourdieu suggests include the relationships between material and nonmaterial (mental, symbolic, or meaningful) social life, between economic and noneconomic (cultural) life, between objective and subjective knowledge, between internal and external factors of individuals, between mechanical and teleological causalities, between agents' and scientists' conceptions, between crystallizations and continuous flux of social reality, and, lastly, between theoretical and practical points of view. Among these social problems, the relationship between internal and external factors of individuals is the most relevant problem to my proposed study. In an effort to solve these social problems, Bourdieu mainly explores the notion of symbolic power, such as economic, social, or cultural capital and social classes, and power of

structure, such as habitus (i.e., a social space historically created through interactions of structure and agency).

Bourdieu (2012) explains the notion of symbolic power, especially the power of cultural and social capital, which can also be converted into economic capital. He (2012:339) states:

> Social space is constructed in such a way that agents or groups are distributed in it according to their position in statistical distributions based on the two principles of differentiation which, in the most advanced societies … are undoubtedly the most efficient: economic capital and cultural capital.

Through this passage, Bourdieu illustrates that social space consists of agents and groups, while economic and cultural capital determine the social class of those agents and groups. He (1986:1) further argues:

> The social world is accumulated history, and if it is not to be reduced to a discontinuous series of instantaneous mechanical equilibria between agents who are treated as interchangeable particles, one must reintroduce it into the notion of capital and with it, accumulation and all its effects.

For Bourdieu, capital as a form of social structure consists of both the accumulated labor of individuals and their social energy. Here, social energy is more than that of accumulated individuals but is relevant to individuals. In short, social structure and individual agents within the society continuously shape each other.

Bourdieu explores three forms of capital—economic, cultural, and social—and claims that these forms of capital are convertible. Accordingly, he argues that while economic capital turns into cultural and social capital, cultural and social capital turn into economic capital. He also suggests that property rights are an institutionalized mode of

economic capital, educational qualifications are an institutionalized mode of cultural capital, and a title of nobility is an institutionalized mode of social capital. In other words, an ability or talent that generates economic capital is the product of an investment of cultural capital. For example, social and cultural stratifications cause inequalities in children's academic success, thus leading to economic disparities. As cultural capital converts into an asset of the market, Bourdieu (1986) argues that it generates symbolic power and class distinctions. Because three forms of capital (constraint) determine individual mobility to upper class (agency), Bourdieu's illustration of economic, social, and cultural capital shows how structure constrains agency. By drawing on Bourdieu's notion of symbolic power, I examine how economic, social, and cultural capital constrains or shapes individual agency in the process of cross-national knowledge sharing and production.

According to Bourdieu (2012), not only does social structure determine individual or group agency, but also agents continuously build social structures through habitus. Since habitus is the social space generated historically through interactions of objective probabilities (structure) and subjective aspirations (agency), it is flexible, and this flexibility strongly structures the rules and regulations of society. According to Bourdieu (2012), habitus generates individual and collective perceptions, thoughts, and actions that continuously change over time. In this process, habitus incorporates past experiences that guarantee the constancy of practices. Therefore, past experiences of individuals and collectives influence the rules and regulations of society while the rules and regulations affect individual and collective practices. In other words, within habitus, the relationship between social structure and individual actors is not unidirectional.

Rather, it is multidirectional, and, thus, both social structure and actors influence each other.

Despite the explanation of the multidirectional relevance between structure and agency in society, Bourdieu's concepts of symbolic power and habitus do not sufficiently examine the power of individual will. That is, while Bourdieu criticized the problems with a dichotomous approach to social problems, both concepts of symbolic power and habitus emphasize the power of structure over individual will. For example, within habitus, individuals possess limited agency, which has been already determined by embodied symbolic power, such as economic, social, and cultural capital. In addition, critics have suggested that Bourdieu's concepts may be too ambiguous (Brubaker 1993, King 2000). That is, unclear definitions for capital and habitus make it difficult to practically apply these concepts. However, despite weaknesses, symbolic power and habitus are important concepts that explain the flexible features of structure and agency associated with international research collaboration. As Bourdieu explained, the relationship between structure and agency is flexible because both continuously shape each other.

We can further understand this flexibility through Bourdieu's article, "The Specificity of the Scientific Field and the Social Conditions of the Progress of Reason." Through this article, Bourdieu criticizes the idea that objective truth (pure science) exists irrespective of social conditions. According to Bourdieu (1975:31), "Even the 'purest' science is a social field like any other, with its distribution of power and its monopolies, its struggles and strategies, interests and profits, but it is a field in which all these invariants take on specific forms." That is, as a social structure, science consists of

different interest groups, such as intellectual, political, and bureaucratic groups. Therefore, a grant agency or even an inventor alone cannot force others to credit what it created as scientific knowledge. Intellectual, political, social and bureaucratic agencies together determine what science is and all these variants are complexly interwoven within society. Because these agencies are closely intermingled, it is difficult for even scientists to distinguish the differences between internal and external interests. According to Bourdieu (1975:32), "it is pointless to distinguish between strictly scientific determinations and strictly social determinations of practices that are essentially *overdetermined*." Thus, science as a structure is very flexible.

To explore the relationship between structure and agency, this part of the dissertation discussed Bourdieu's perspective on knowledge production in society. He connects the structure-agency divide using the concepts of symbolic power and habitus. According to Bourdieu, society consists of individual and group agents, but symbolic powers, such as economic, social, and cultural capital, limit their activities within society. Moreover, it is noteworthy that Bourdieu suggested flexibility in the relationships among structures and agencies. That is, he shows that social structures, such as social, cultural, and economic capital, are convertible, but also illustrates that both structure and agency simultaneously shape each other within habitus.

Bourdieu's concepts of symbolic powers and habitus are closely related to the process of cross-national knowledge sharing and production examined in this study. Analyzing two international collaborative projects in a bridge country with partners in developed and developing countries, this study reveals the interactions between social structures and individual agency. That is, two cases of cross-national research

collaboration disclose structural catalysis and obstacles, as well as individual agency, that influence knowledge sharing among participants in countries with various degrees of development. I argue that social structures, such as economic, social, and cultural capital, both promote and constrain the joint research projects between countries with structural discrepancies, while individual agency sustains bilateral knowledge sharing and production among participants. Therefore, the process of cross-national knowledge sharing and production in this study is habitus in which structure and agency shape each other simultaneously. More importantly, this study suggests that not only the power of social structures, but also the power of individual will determine the process of cross-national knowledge sharing and production in a bridge country that has recently made a transition in its developmental status.

2-2. Research Design and Sites

From January 2018 to February 2019, I conducted fieldwork in mechanical science and engineering laboratories in Korea for a period of eleven months, in Tanzania for one month, and in the US for two months. While spending more time in Korea than in Tanzania and the US, I was able to gather the perspectives of Tanzanian and U.S. researchers[9] through online conferences between Korean teams and other teams. Methodologically, the study utilizes qualitative approaches including ethnography of two joint research projects, such as participant observation of formal and informal meetings and laboratories, as well as semi-structured interviews with the participants engaged in

[9]In this study, "researchers" refers scientists and engineers engaged in two case projects, and "scientists" and "engineers" are used interchangeably.

the joint projects. I also referenced the memorandum of understanding, websites, journal articles, and Tanzanian local newspaper articles.

As for ethnography and participant observation, Babbie (2016) has asserted that taking detailed notes of ongoing scenes and actions in the field effectively captures the social process. The author suggested that despite the difficulties in observing and recording everything in the field, researchers should include both observations and interpretations in their notes. Furthermore, he argued that researchers should be prepared for unanticipated situations even though preparing protocols in advance is helpful for taking notes on important observations in the field. The strengths of ethnography and participant observation, as well as other qualitative field research, are found of in the depth of understanding and the flexibility of research design that they afford (Babbie 2016).

To examine S&T collaborative projects in Korea with a developed and developing country, I selected a mechanical engineering laboratory in Korea that conducts joint research projects with laboratories in the US on nanoparticle deposition systems and Tanzania on energy and sustainability. To select a Korean laboratory that conducts joint research projects with both developed and developing countries, I had informal conversations with 30 Korean graduate students I met through a Korean graduate student organization at a research-based university in the US. I identified one Korean laboratory by asking the students whether they knew of any laboratory collaborating with both US and developing countries. To prevent possible disclosure of personal identifiers, I use pseudonyms of universities and individuals in this study.

I contacted the principal investigator (PI) of a Korean laboratory. In turn, the PI in the Korean laboratory identified collaborative or partner laboratories in the US and Tanzania. A student engaged in the collaborative project between the laboratories in Korea and the US facilitated my introduction to a PI in the US. I met the PI in person in the US to request permission to study their collaborative research. As for the Tanzanian partner, the Korean PI contacted collaborators in Tanzania, explained my research, and subsequently, I received permission to conduct my field research at a national university in Tanzania.

The Korean research team that I selected conducts research on materials and manufacturing, including rapid prototyping, micromachining, nanocomposites, and functionally graded materials. In collaboration with a laboratory in the US, the Korean team is conducting research on a laser that laminates metallic nanoparticles, such as aluminum or copper, on a flexible substrate made of polymers. This flexible device is applicable to nanosized robots or sensors by controlling actuators. In 2015, the U.S. and Korean universities established a joint Ph.D. program in the field of mechanical engineering. The Korean research team began collaborating with the U.S. research team by sending a graduate student to the U.S. laboratory to work with a co-advisor.[10] Through email communication, the PIs established a joint research project. The joint project ended in 2019 with the student's completion of a Ph.D. degree.

For their joint research project, the U.S. team focuses on the development of simulation programs through computational modeling, while the Korean team focuses on

[10]The student who pursued a dual Ph.D. degree in the US and Korean universities returned to Korea after eleven months of stay in the US and then also worked as a post-doctoral fellow in the Korean team.

the development of an end product through testing and manufacturing. The joint project is funded by the Brain Korea 21 Plus project of the NRF,[11] which provides funding for international collaborative research projects in Korean universities that support graduate-level human resources in science and engineering. During the stay in the US, the Korean doctorate student worked as a research assistant on a research project funded by the NSF. The success or failure of the project was to be determined by the development of breakthrough computational models and that of a less expensive and non-toxic printing machine. Even though the project would eventually lead to the development of actual products, the requirement of the funding agencies (the NRF and the NSF) was the publication of relevant journal articles.

In contrast to the aforementioned joint research project with the US, a joint research project between the Korean university and a Tanzanian university centers on the implementation of power transmission grids in rural areas for the distribution of solar energy. In 2017, the Korean and Tanzanian universities launched a joint research center, which has been funded by the NRF for four years. This center aims to develop, educate, and commercialize innovative technologies that are suitable for the environment in Tanzania. The Korean and Tanzanian PIs met each other through a Korean NGO worker who had worked in Tanzania. In advance of beginning the collaborative project with the Tanzanian partner, the Korean research team had successfully completed an ODA project funded by the NRF regarding sustainable energy in high mountain areas in Nepal and was searching for a new collaborative partner from another developing country. This prior experience enabled the Korean team to continue projects in the field of ODA.

[11]The NRF is a government-funded agency.

During the demand survey of the NRF, the Korean PI met a person from a Korean NGO who knew a Tanzanian PI. The PIs met through a mutual friend. Then, the PIs applied for the ODA project funded by the NRF together. The collaborative project was approved in April 2017. The teams established a research center in a Tanzanian government-funded university. The project was scheduled to end in 2020. Through the center, both Korean and Tanzanian teams implemented and tested a solar panel that provides electricity, as well as a smart-meter system, which uses a smart phone to monitor the amount of electricity in rural Tanzania, where geographical accessibility tends to be low. The success or failure of this project would be determined by the actual implementation and operation of solar panels and smart-meter systems in rural Tanzania.

During my fieldwork, I observed interactions among participants engaging in the joint projects, including laboratory and field experiments, meetings, and conferences. I took detailed notes or short memos on my observations based on a protocol aligned with my research questions. Approximately twenty researchers and technicians in Korean, U.S., and Tanzanian laboratories participating in the joint projects were observed and interviewed. In particular, I interviewed a Korean professor who was directing and managing joint projects with the US and Tanzania, one U.S. professor who was supervising a Korean student through a joint degree program, one Korean local director, two Tanzanian professors who were participating in the joint project between Tanzania and Korea, one Korean doctoral student participating in the joint degree program between the U.S. and Korean universities, five Korean students in the Korean research team participating in the joint research project between Tanzanian and Korean universities, two staff members (one Korean and one Tanzanian) in the research center located in the

Tanzanian university, one director of a social enterprise in Tanzania, two Korean and three Tanzanian staff members in the social enterprise (or NGO[12]) that serves as a gatekeeper between the Tanzanian and Korean PIs, and one administrative staff member working on the Korean research team.[13]

Table 1-1. The List of Interviewees

Position	The number of interviewees
Korean professor	1
U.S. professor	1
Tanzanian professor	2
Graduate students in Korea	6
Directors and staff members in Tanzania	9
Korean administrator	1
Total	20

The Korean PI had weekly team meetings of one and a half hours for all students and monthly individual meetings of thirty minutes for each student. I attended weekly and monthly meetings, as well as laboratory experiments, to observe the interactions between the PI and students, in addition to discussion of research on computational models and printing machines. I took detailed notes or short memos during these

[12]NGO that participated in the joint project between Tanzania and Korea later merged into a social enterprise
[13]For the list of interviewees, see table 2-1

observations. Sometimes, I also received meeting minutes written by a student in the Korean laboratory.[14] The student who was pursuing the dual degree program in both Korean and U.S. universities had a one-hour weekly meeting with the U.S. advisor through Skype. I observed this meeting once a week and took detailed notes of the conversations between the professor and the student. The Korean and Tanzanian research team provided office space so that I could interview and meet them during meetings or experiments. In Korea and Tanzania, I conducted my fieldwork daily by observing informal discussions among the team members. Furthermore, I visited the U.S. laboratory to interview the U.S. PI, attend a laboratory meeting, and observe research facilities related to the joint research project.

To understand from a managerial standpoint, I also interviewed the relevant administrative staff member on the Korean research team. I conducted face-to-face interviews or conference calls with participants who granted me permission (N = 20; 95% response rate). The duration of the interviews ranged from 30 minutes to one hour. Georgia Tech Institutional Review Board (IRB) approval was obtained prior to conducting participant observation and interviews. I received informed consent prior to each interview. The interview questions (see appendix) focused on general descriptions of the interviewees' research and explanations of their experiences in international research collaborations. I interviewed Korean participants in Korean, while interviewing U.S. and Tanzanian participants in English. I took detailed notes in interviews for cases in which interviewees declined to be audio recorded.[15] After the recording and

[14]I collected nine meeting minutes.
[15]In total, I wrote 219 pages of detailed notes and short memos during my fieldwork.

transcribing of the interviews was complete, personal identifiers were removed for the protection of the personal information of the interviewees.

According to Weiss (1994), analytic processing of interview data includes coding, sorting, local integration, and inclusive integration. Here, coding refers the categorization of data, sorting represents the narrowing down of coded data, local integration means the organization of sorted data in each section, and inclusive integration signifies the development of a framework that leads to general conclusion (Weiss 1994). For this study, in the process of coding, common themes based on Bourdieu's notion of structural power (economic, social, cultural capital) and individual agency (personal inspiration) were derived as structural and individual promoters of and barriers to the process of knowledge sharing and production. In addition, the collaborative networks of university, government, and industry, as well as similarities and disparities between the two projects, were identified for analysis.

After coding was finished, sorting and local integration occurred simultaneously. I sorted highlighted excerpts by organizing them in each section of my dissertation. Then, during the stage of inclusive integration, I applied data in each section to an overall framework. As Weiss (1994) also addressed, the four stages (coding, sorting, local integration, and inclusive integration) occurred throughout the whole process of this study. For example, while writing notes and memos in the field, I highlighted parts related to structure and agency, or while integrating sorted data to each section of my dissertation, I had to go back to the transcribed data and extract more excerpts. Even during the process of inclusive integration, I had to review my notes, memos, and interview data for concrete analysis. At the beginning of data analysis, I considered using

a software tool[16] to analyze the data collected. However, the software was only available for English data analysis, while a large part of the data I collected was in Korean. As I mentioned previously, I interviewed Korean participants in Korean and then personally translated Korean transcripts to English. While I transcribed entire English interviews with the U.S. and Tanzanian participants of my study, I only translated previously sorted data from the Korean interviews. Because the process of coding and sorting occurred when I translated Korean data, I did not use software to analyze the data in this study.

In this study, my presence as a social researcher in the field inevitably influenced the interactions of participants. Ethnographic participation, according to Emerson et al. (1995:3), refers to "a deeper immersion" into the daily lives and activities of people. While this immersion enables field researchers to understand the daily lives of people, Emerson et al. (1995) suggested that the views of field researchers are influenced by people in the study, and the presence of field researchers unavoidably influences the actions of people in the study. Franklin and Roberts (2006) also suggested that the ethnographer's own involvement in a situation produces research questions rather than answers. That is, the close interaction between a researcher and participants of a study becomes the part of the research.

Personal encounters in ethnographic research have raised the question of scientific objectivity (Emerson et al. 1995; Burawoy 1998; Franklin and Roberts 2006). However, Emerson et al. (1995) claimed that the impact of field researchers does not disrupt ongoing patterns in the field. Instead, close interactions with people in the study offers researchers a more profound understanding (Emerson et al. 1995). In a similar vein,

[16]HyperRESEARCH

Burawoy (1998) asserted that the reflexive approach, which acknowledges the impact of a researcher in the field, provides objectivity to the study by including interactions between observer and participants. Therefore, acknowledging the impact of my own personal interaction with participants in the field to the process of knowledge sharing and production, I have included reflexivity in the summary of my analysis.

In addition to participant observations and interviews, I referenced relevant documents and websites, such as memorandum of understanding (MOU 2014), websites of each research team (IDIM 2018, ITEC 2018, MSSE 2009), journal articles published by participants in the Korean teams (Song et al. 2018, Song et al. 2020, Wang et al. 2020, Wang et al. 2020, Wang et al. 2021), and Tanzanian local newspaper articles (IPP Media.com 2018a, IPP Media.com 2018b), regarding the joint research projects and conferences. Throughout this study, relevant documents and websites were used to verify the data gathered by observations and interviews.

Following a review of previous literature regarding academic research collaboration and Bourdieu's concept of symbolic power and habitus, this section of the chapter discussed research design and sites in which the study was conducted. In brief, this study examines two collaborative research projects in a Korean university using ethnography, participant observation, and interviews. As the collaborative projects were conducted with U.S. and Tanzanian universities respectively, this study describes cross-national knowledge sharing and production between countries with various degrees of development. Prior to discussing the collaborative projects in detail, the next chapter of this dissertation examines the national contexts of Korea, the US, and Tanzania.

CHAPTER 3. NATIONAL CONTEXTS

The economic, political, and social contexts of each nation are inseparable from the development of S&T in each nation and thus influence micro-level interactions in research collaboration. To understand the national contexts of Korea, the US, and Tanzania, this chapter reviews (1) the development of S&T in each country in relation to the trends of research and development (R&D) expenditures, gross domestic product (GDP), gross national income (GNI), and tertiary level school enrollment rate, (2) bilateral US-Korea and Tanzania-Korea relationships, and (3) disparities between collaborative research projects conducted by a Korean research team with U.S. and Tanzanian partners.

3-1. Trends of R&D Expenditure, GDP, GNI, and School Enrollment Rate

Since World War II (WWII), the US has emerged as a global leader in S&T (Bush 1945). Bush (1945:5) explains:

> [a]dvances in science when put to practical use mean more jobs, higher wages, shorter hours, more abundant crops, more leisure for recreation, for study, for learning how to live without the deadening drudgery which has been the burden of common man for ages past. Advances in science will also bring higher standards of living, will lead to the prevention or cure of diseases, will promote conservation of our limited national resources, and will assure means of defense against aggression. But to achieve these objectives – to secure a high level of employment, to maintain a position of world leadership – the flow of new scientific knowledge must be both continuous and substantial.

Here, “advances in science” refers to the development of basic research, “practical use” represents innovation, and “higher standard of living” indicates the outcome of economic

growth. More importantly, “the flow of new scientific knowledge” can be interpreted as a linear linkage of basic to applied innovation. The linear model has been criticized by scholars because of the lack of evidence that shows a clear correlation between economic growth and basic research (Edgerton 2004; Scranton 2006). For example, Scranton (2006) asserted that a variety of actors are involved in the process of innovation. Consequently, he argues that it is difficult to predict the result of technological development. Regardless of its flaws, the linear model played a vital role in providing a rationale and justification for government investment in the development of S&T for maintaining the status of the US as a global leader.

Until the 1970s, S&T in Korea mainly adopted and imitated foreign technologies (Hemmert 2007). Industrial R&D was emphasized in the 1980s, while basic research capabilities have been built up since the 1990s. Hemmert (2007: 30) suggested that the Korean S&T policies sought to transition from a “technological catch-up nation” to a “contributor of cutting-edge knowledge” by expanding R&D resources after 1997. In addition, the rapid growth of the Korean economy in the 1990s led to a continuous increase in R&D investment in Korea (Bark 2004, Wagner et al. 2003). Because the government-driven investment in science and technology during the 1970s and 1980s was positively associated with the national economic growth, the Korean government stressed the importance of overcoming the financial crisis in 1997 through R&D (Bark 2004). Figure 3-1 shows the trend in research and development expenditure as a percentage of GDP in Korea, the US, and Tanzania.

As shown in Figure 3-1, companies, research institutes, universities, and government laboratories in Korea have increased their proportion of R&D expenditures

since the end of the 20th century, reaching around 4% in 2015. At the same time, the US maintained its R&D expenditures at around 2.5% of its GDP. The percentage of R&D expenditure out of total GDP for Tanzania is only available for three years: 0.34% for 2007, 0.38% for 2010, and 0.53% for 2013. Even though R&D expenditure as a percentage of GDP does not sufficiently explain national conditions in science and technology, this figure suggests that since 2004–5, Korea has invested a larger percentage of its GDP on the development of S&T compared to the US and Tanzania. However, in terms of the total amount of money spending on R&D, the amount of money spent by Korea in 2016 (75.9 billion USD) was not comparable to the amount of money spent by the US (464.3 billion USD) in the same year. As of 2016, in total, the US spent 16 times more money than Korea on R&D (OECD 2018).[17]

[17]R&D Expenditures per capita: US (1,437.09 USD), South Korea (1,481.54 USD)

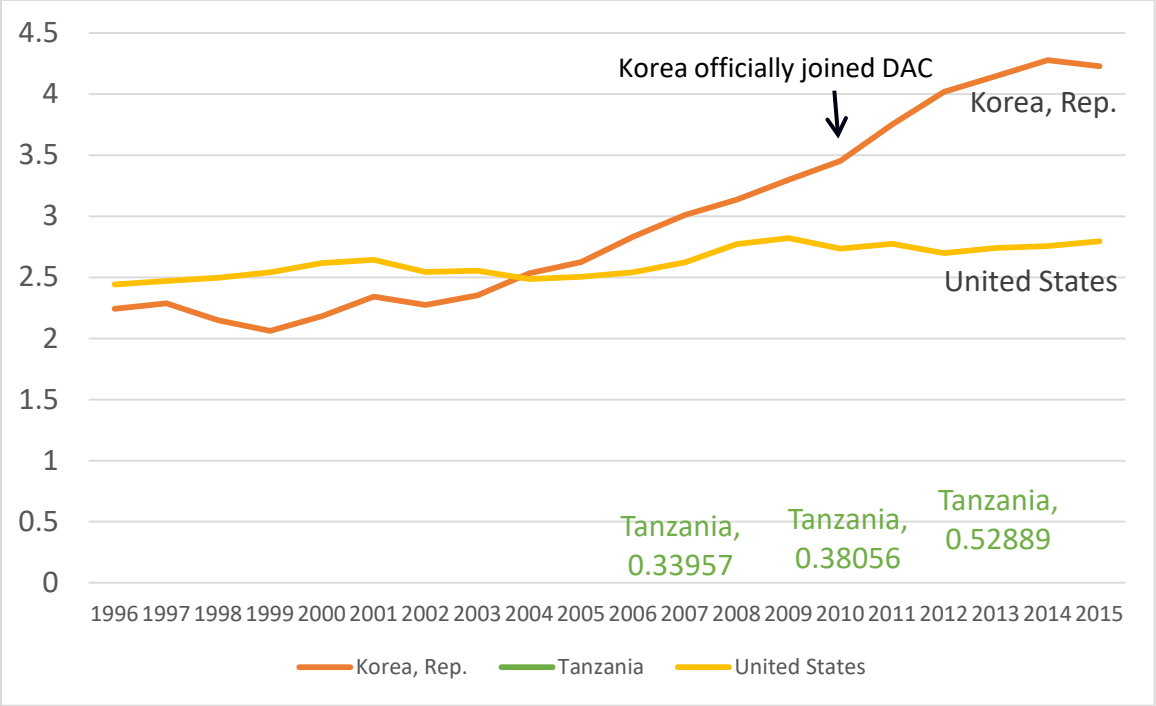

Figure 3-1. Research and Development Expenditure (% of GDP): Korea, US, and Tanzania
Source: United Nations Educational, Scientific, and Cultural Organization (UNESCO) Institute for Statistics.[18]

[18]The gross domestic expenditure on R&D indicator consists of the total expenditure (current and capital) on R&D by all resident companies, research institutes, university and government laboratories, etc. It excludes R&D expenditures financed by domestic firms but performed abroad. The OECD's Frascati Manual defines research and experimental development as "creative work undertaken on a systemic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications." R&D covers basic research, applied research, and experimental development. (1) Basic research - Basic research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view (2) Applied research - Applied research is also original investigation undertaken in order to work acquire new knowledge; it is, however, directed primarily towards a specific practical aim or objective. (3) Experimental development - Experimental development is systematic work, drawing on existing knowledge gained from research and/or practical experience, which is directed to producing new materials, products or devices, to installing new processes, systems and services, or to improving substantially those already produced or installed. The fields of science and technology used to classify R&D according to the Revised Fields of Science and Technology Classification are: 1. Natural sciences; 2. Engineering and technology; 3. Medical and health sciences; 4. Agricultural sciences; 5. Social sciences; 6. Humanities and the arts. The data are obtained through statistical surveys which are regularly

As for Tanzania, even though the expenditures on S&T increased during the 1980s, its overall expenditures were much lower, and much of the expenditures relied upon international funding (COSTECH 2012). That is, financial constraints limit the growth of the capacity for S&T in Tanzania. Through the introduction of foreign aid in the 1980s, the Tanzanian government established economic development programs, such as the National Economic Survival Program in 1981, the Structural Adjustment Program in 1982, the Economic Recovery Program in 1986, and the Economic and Social Action Program in 1989 (Enos 1995). Even though these economic programs do not consist of direct plans for S&T development, the development of the economy would eventually lead to the reduction of foreign dependency for S&T expenditures in Tanzania.

In a recent classification of countries in terms of GNI, the World Bank defined Tanzania as a country with a low-income economy (referring to countries with a GNI per capita of $1,005 or less) and Korea and the US as countries with the high-income economies (countries with a GNI per capita of $12,236 or more). In terms of level of economic development considering trade policy and geopolitical tensions in addition to per capita GNI, the United Nations (UN; 2020) categorized the US as a developed country and Korea and Tanzania as developing countries. Based on the compiled data of per capita GNI, the Human Assets Index, and an economic vulnerability index, Tanzania is a least developed country (LDC; UN 2020).

The GDP and GNI trends highlight the developmental stages of the U.S., Korea, and Tanzania. For example, Figure 3-2 shows that the trend of per capita GDP for the US,

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conducted at national level covering R&D performing entities in the private and public sectors. (https://data.worldbank.org/indicator/GB.XPD.RSDV.GD.ZS?locations=KR-US-TZ-EU)

Korea, and Tanzania has varied over the last 60 years. While per capita GDP for Korea was somewhat analogous to Tanzania until 1970, it significantly increased after the 1970s. In 2016, GDP per capita in the US was 53,015 USD, Korea's GDP per capita was 36,151 USD, and Tanzania's was 2,518 USD. The GDP per capita for the US was almost 1.5 times higher than that of Korea and 20 times higher than that of Tanzania. Similarly, Figure 3-3 shows the trend of per capita GNI for the US, Korea, and Tanzania. Even though per capita GNI data for Tanzania is only available from the end of the 20th century, existing data indicates that the gap between the per capita GNI of these three countries has increased since the 1990s. As of 2016, GNI per capita for the US was 56,850 USD, Korea's GNI per capita was 27,600 USD, and Tanzania's was 900 USD.[19] That is, GNI per capita for the US was approximately twice than that of Korea and 63 times higher than that of Tanzania.

In addition to GDP and GNI, the tertiary level school enrollment rate (gross)[20] indicates the varied educational contexts of the three countries. Similar to the trends in GDP and GNI, the school enrollment rate at the tertiary level was low in Korea and Tanzania in the 1970s, but it has gradually increased since the 1980s in Korea. Figure 3-4 shows that in the 1970s, the gap between the tertiary level school enrollment rate of Tanzania and Korea was relatively small, while the gap between the tertiary enrollment rate of the US and Korea was large. However, since 1999, the enrollment rate for Korea has exceeded the enrollment rate for the US. As reflected in Figure 4, the level of

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[19]See https://datahelpdesk.worldbank.org/knowledgebase/articles/906519

[20]Gross enrollment ratio is the ratio of total enrollment, regardless of age, to the population of the age group that officially corresponds to the level of education shown. Tertiary education, whether or not to an advanced research qualification, normally requires, as a minimum condition of admission, the successful completion of education at the secondary level.

education in Korea has continually increased after the 1980s and the school enrollment rate at the tertiary level reached 95.86 in 2018. That tertiary enrollment rate was 88.29 in the US in 2018 and 3.09 in Tanzania in 2019.

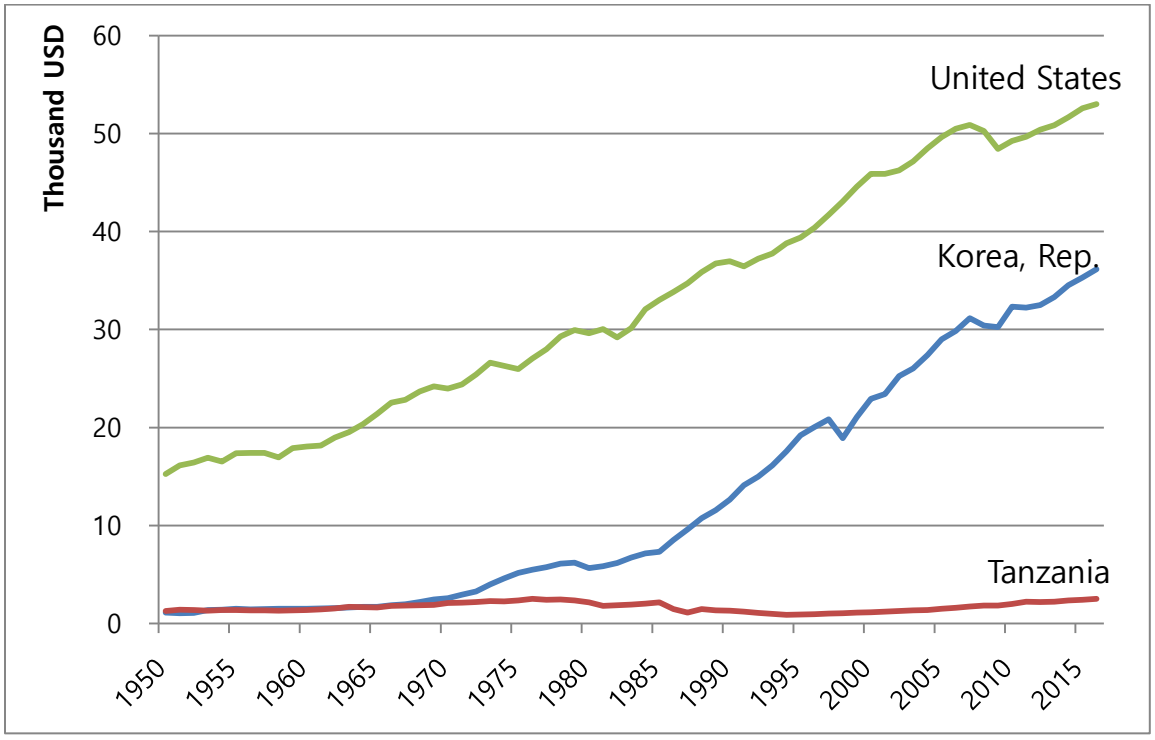

Figure 3-2. Real GDP per capita for the US, Korea, and Tanzania

Source: Maddison Project Database[21]

[21]Maddison Project Database, version 2018. Bolt, Jutta, Robert Inklaar, Herman de Jong and Jan Luiten van Zanden (2018), "Rebasing 'Maddison': new income comparisons and the shape of long-run economic development." (Maddison Project Working Paper, nr. 10, available for download at www.ggdc.net/maddison)

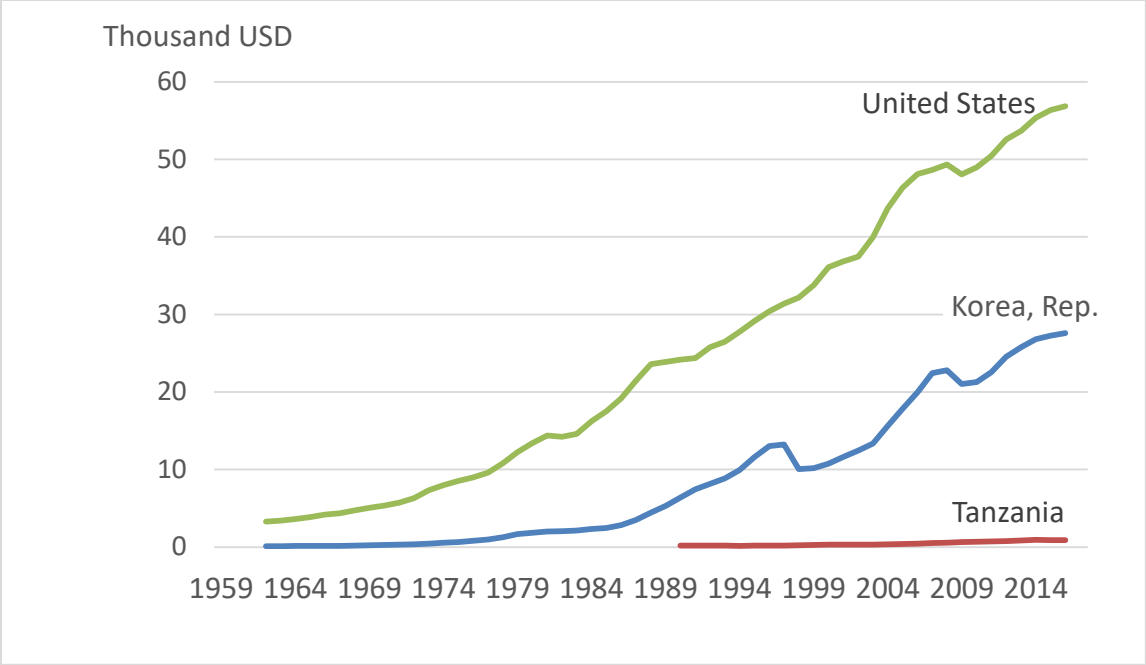

Figure 3-3. GNI per capita for the US, Korea, and Tanzania

Source: World Development Indicators (The World Bank National Accounts data, and OECD National Accounts data files)[22]

[22]GNI per capita (formerly GNP per capita) is the gross national income, converted to US dollars using the World Bank Atlas method, divided by the midyear population. GNI is the sum of value added by all resident producers plus any product taxes (less subsidies) not included in the valuation of output plus net receipts of primary income (compensation of employees and property income) from abroad. GNI, calculated in national currency, is usually converted to US dollars at official exchange rates for comparisons across economies, although an alternative rate is used when the official exchange rate is judged to diverge by an exceptionally large margin from the rate actually applied in international transactions. To smooth fluctuations in prices and exchange rates, a special Atlas method of conversion is used by the World Bank. This applies a conversion factor that averages the exchange rate for a given year and the two preceding years, adjusted for differences in rates of inflation between the country, and through 2000, the G-5 countries (France, Germany, Japan, the United Kingdom, and the US). From 2001, these countries include the Euro area, Japan, the United Kingdom, and the US. Tanzania: Covers mainland Tanzania only. (https://data.worldbank.org/indicator/NY.GNP.PCAP.CD?locations=TZ-KR-US&start=1962&end=2016&view=chart)

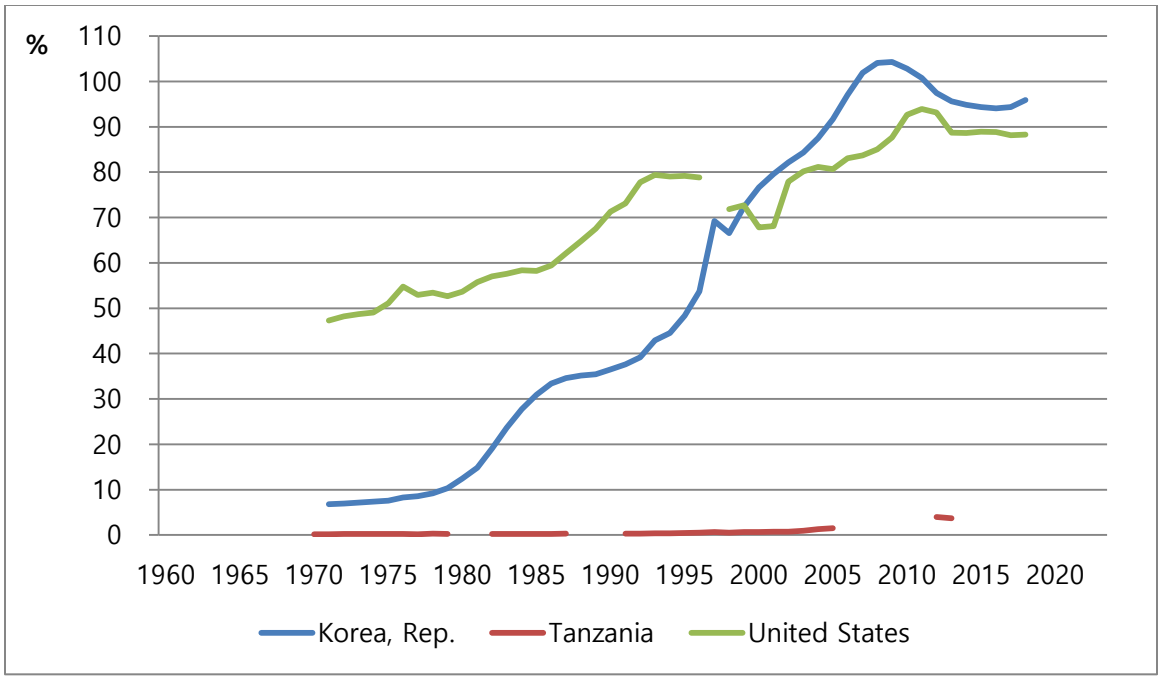

Figure 3-4. School Enrollment Rate at the Tertiary Level (% gross)

Source: UNESCO Institute for Statistics (uis.unesco.org). Data as of September 2020.

Using statistical data such as R&D expenditure per GDP, GDP per capita, GNI per capita, and the school enrollment rate at the tertiary level, this section of Chapter 3 discussed the national contexts of Korea, the US, and Tanzania in terms of science and technology, economics, and education. The statistical data implied that Korea, Tanzania, and the US are at differing levels of development. In particular, according to the categorizations of the World Bank and OECD, Korea is a high-income developing country that emphasizes investment on the development of science and technology, as well as education. In addition to the national context of each country, which shows the unevenness of S&T and economy between each, the bilateral relationships between the US and Korea and between Tanzania and Korea represent the history of political

relationships between Korea and the two other countries. The following section examines the bilateral US-Korea and Tanzania-Korea relationships.

3-2. Bilateral Relationships

3-2-1. Bilateral relationship between Korea and the US

Historically, the science and technology relationship between the US and Korea has transitioned reflecting the diplomatic and economic relationships between two countries (STEPI 2001; Wagner et al. 2003). The diplomatic relationship between Korea and the US began in 1949 after the Korean peninsula was divided into two nations, the Republic of Korea (ROK) in the south and the Democratic People's Republic of Korea in the north at the end of the WWII (BEAPA 2018; Manyin et al. 2020). That is, diplomatically, the security needs in South Korea against North Korea and the strategic interest of US in northeast Asia against the communist powers during the Cold War led to the establishment of a security alliance between the US and South Korea (Lee 2006; Snyder 2012; Shin et al. 2015; Heo 2018).

Snyder (2012) suggested that the US-ROK Mutual Defense Treaty signed in October 1953 was the beginning of South Korea's dependency on the US for its military defense. The signing of the Mutual Defense Treaty shows that the diplomatic relationship between Korea and the US, which is closely tied to the S&T relationship between the two countries, began in response to threats from North Korea and the communist powers during the Cold War era. After the Korean War (1950-1953), because South Korea was an "essential link in its regional anti-Communist containment system in North-East Asia," the US began providing military and economic assistance, including technological aid, to

South Korea (Lee 2006: 37).

During the 1950s and 60s, South Korea saw developments in S&T through receiving technological aid from the US as part of its postwar recovery.[23] The Science and Technology Policy Institute (STEPI) report (1999) suggested that from 1950 to 1964, the US offered 72,986 USD to South Korea as technological aid. During this period, the S&T relationship between the two countries focused on training South Korean engineers and establishing an S&T educational system in South Korea (STEPI 1999). According to the STEPI report (1999), using the postwar financial support from the US, South Korea sent 2,236 engineers to and invited 1,002 technological experts from other countries for training engineers. The report also indicates that the US was the largest source of technological aid in South Korea and thus heavily influenced the development of South Korean S&T.

After 1965, technological aid from the US focused on launching S&T research institutions in Korea. Accordingly, in 1971, using aid from the US, the Korean government established the Korea Advanced Institute of Science and Technology (KAIST), the first institution for higher education in the fields of science and technology (STEPI 1999). Developmental aid from the US ended in 1976, and the S&T relationship between the US and Korea transitioned from a unilateral to a bilateral relationship (STEPI 1999). For example, the NSF and the Korea Science and Engineering Foundation (KOSEF) launched joint research programs in 1985, and the US and Korea jointly founded the Korea Institute of Science and Technology (KIST), the first national research institution in Korea in 1986 (STEPI 1999).

[23]Also, the US had strategic interest in (South) Korea after the war (See https://www.cfr.org/excerpt-us-south-korea-alliance)

The bilateral cooperation between the US and Korea continued in the 1990s through the initiation of a forum for US-Korea S&T collaboration in January 1993. At the forum, policy makers, S&T leading members, and industrial leaders from both countries discussed the future direction of S&T cooperation between the two countries (Mitchell 1997, STEPI 1999). In 1995, to reinforce its S&T partnership with the US, the Korean government decided to invest one million dollars per year to facilitate special programs, such as the establishment of Korea-US Science Cooperation Center (Mitchell 1997, STEPI 1999). Located in Washington, D.C., this center supports R&D, S&T education, and networking for Korean or Korean American researchers and students residing in the US. In particular, the center facilitates networking for S&T researchers and students in the US and Korea.[24]

The cooperation between the US and Korea has expanded along with the economic growth of Korea. According to a fact sheet published by the Bureau of East Asian and Pacific Affairs in the US, a deep and comprehensive partnership between the US and Korea has continuously grown in recent years (BEAPA 2018). For example, Korea's foreign direct investment in the US has increased between 2011 and 2016 from 19.7 billion USD to 38.8 billion USD, which marks the second largest investment in the US amongst Asian countries (BEAPA 2018). At an individual level, Korean researchers have conducted more S&T collaborative projects with U.S. partners than researchers in other countries because many Korean researchers pursued higher education in the US

[24]See http://www.kusco.org

(STEPI 1999). In addition, Korea sends the third largest number of international students to the US (BEAPA 2018, IIE 2019).[25]

3-2-2. Bilateral relationship between Tanzania and Korea

In a similar vein as the relationship between the US and Korea, the S&T relationship between Tanzania and Korea works in association with the political and economic relationship between the two countries. According to Kim (2019), the competition between North and South Korea triggered South Korea's interest in African continent. That is, the political ties between South Korea and Africa were weak until North Korea attempted to enter the UN in 1982. In 1982, Korea made its first presidential visit to Kenya, Nigeria, Gabon, and Senegal, but South Korea's interest in Africa did not continue after it gained UN membership (Kim 2019). Kim (2019) also suggested that the Ban Ki-moon running for UN Secretary-General restarted the push for political ties between Korea and the African continent in 2006. In 2006, Korean President Roh Moo-Hyun made a subsequent visit to the African continent. According to Kim (2019), while the competition between North and South Korea initiated the political relationship between Korea and African continent, regional competition amongst East Asian countries grew these ties.

The bilateral relationship between Tanzania and Korea began with the distribution of developmental aid from Korea to the African continent. In conjunction with the presidential visit to the African continent in 2006, the Korean government launched the "Korea Initiative for Africa's Development" (Kim and Gray 2016). According to Kim and Gray (2016), this initiative offered future directions for Africa-

[25]See https://www.state.gov/u-s-relations-with-the-republic-of-korea/

Korea cooperation, and the Korean government rapidly increased the amount of aid from 64.1 million USD in 2006 to 357 million USD in 2012. By transitioning from a recipient to a donor of ODA in 2010, Korea has emerged as a bridge country between developed and developing countries (Kim et al. 2013; Kalinowski and Cho 2012; Mawdsley 2012; Choi 2011). Positioning Korea as an emerging country in the field of ODA, the Korean government has strategically used aid to develop Africa-Korea relationship. At the same time, Kim and Gray (2016) suggested that recipient countries considered support from emerging donors, like Korea, less exploitative than support from established donors.

As for the Korean government's political use of the aid, Kim and Gray (2016: 651) have stated:

> [T]hrough such high-profile events as the 2010 G20 summit and the 2011 High Level Forum on Aid Effectiveness, Seoul has highlighted South Korea's transition from the relative margins of international politics to the self-ascribed position of 'broker' of global development, capable of bridging the gap between the developed and developing worlds.

The above passage shows that the Korean government emphasized Korea's own experience of transitioning from a recipient to a donor of ODA in addressing the need for Korean aid in Africa. Kim and Gray (2016: 654) also claimed that the economic relationship between Korea and the African continent has been unequal because trade between Africa and Korea has favored Korean exporters in terms of its technical composition. That is, while imports from Africa to Korea contain natural resources, exports from Korea to Africa mostly consist of high-end technical goods.

On the African continent, Tanzania has been the top recipient of the Korean ODA since 2006.[26] The amount of aid from Korea to Tanzania has steadily increased from 21.46 million USD in 2010 to 79.83 million USD in 2014. Table 3-1 shows the trend in financial aid from Korea to Tanzania from 2010 to 2014. As the table indicates, in total, the Korean government provided 229.76 million USD to Tanzania, including both tied and untied aid. Moreover, as Figure 3-5 illustrates, Tanzania became the second largest recipient country of the total Korean ODA in 2016 (OECD 2019). Tanzania is undoubtedly an important cooperative partner to Korea, considering that the Korean government distributed 41.3% of bilateral ODA to its top ten recipient countries: Vietnam, Tanzania, the Philippines, Ethiopia, Cambodia, Afghanistan, Indonesia, Myanmar, Mozambique, and Mongolia.

[26]See Table 3-2, See http://www.odakorea.go.kr/eng.result.RegionCountry_Overview.do

Table 3-1. Trends in Korean ODA to Tanzania from 2010 to 2014

Million USD

	2010	2011	2012	2013	2014	Total
Untied- (grant)	**11.59**	**10.55**	**13.16**	**10.70**	**12.89**	**58.89**
Tied- (loan)	**9.87**	**10.40**	**37.49**	**46.17**	**66.94**	**170.87**
Total	**21.46**	**20.95**	**50.65**	**56.87**	**79.83**	**229.76**

Source: Kim, Cae-One, Kim, Chong-Sup, Park, Bokyeong, and Lee, Eunsuk. 2015. "A Study on the Cooperation Strategy in Establishing the CPS with Tanzania." Korea Institute for International Economic Policy (KIEP). ODA Policy Study 15-03, Research Report 15-43

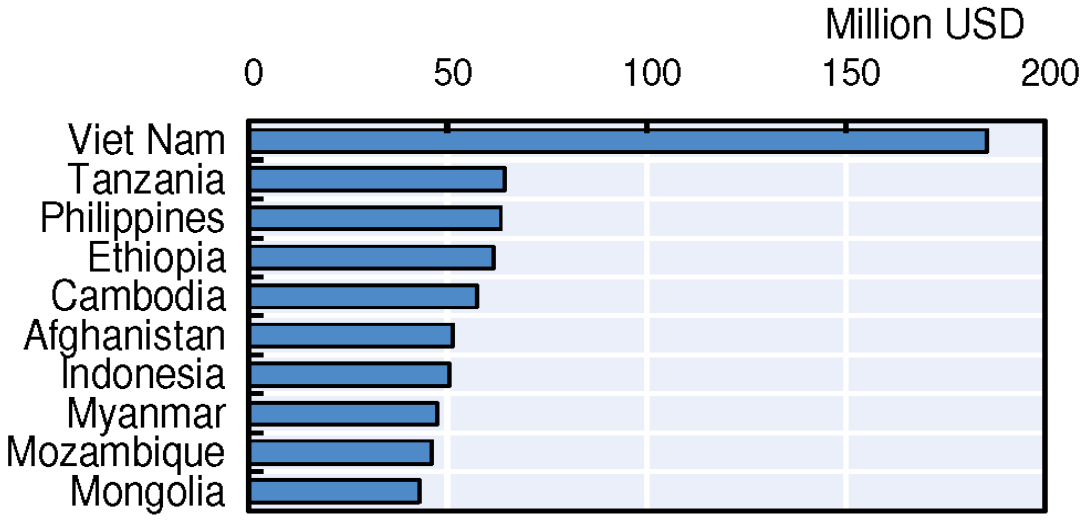

Figure 3-5. Bilateral ODA to Top Recipients, 2016, Gross Disbursements, Korea

Source: OECD. 2019. "Korea," in Development Co-operation Report 2018: Joining Forces to Leave No One Behind, OECD Publishing, Paris

Table 3-2. Amount of Korean ODA to the African Continent from 2006 to 2015

Million USD

Country	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Tanzania	3.84	9.42	7.15	9.19	21.46	20.94	50.64	56.87	79.84	71.29
Ethiopia	2.29	3.30	4.39	4.16	10.20	11.61	20.44	27.34	42.91	46.02
Mozambique	0.13	0.21	0.98	0.43	0.95	6.48	25.13	57.08	56.51	42.29
Ghana	0.27	1.56	2.51	2.47	6.73	5.06	23.44	9.85	15.82	39.84
Uganda	0.16	1.29	0.68	1.24	1.88	2.41	3.99	11.42	12.16	22.95
Rwanda	0.34	0.84	1.35	2.31	6.86	5.82	7.11	12.48	16.46	20.93
Cameroon	0.31	0.27	0.74	0.18	2.57	4.30	15.51	7.18	11.36	16.70
Angola	10.09	17.41	25.92	28.34	18.83	16.75	7.98	10.28	5.38	13.14
Senegal	0.85	2.43	10.25	5.92	14.85	8.71	31.68	17.25	19.86	10.31
Congo	0.31	1.64	2.51	2.16	5.67	5.99	6.85	6.29	11.52	9.71
Mali	0.01	-	0.27	0.42	0.44	12.93	1.10	9.32	7.19	9.15
Kenya	15.47	2.60	1.79	4.50	2.79	9.29	8.98	5.28	3.73	5.92
Morocco	2.40	2.85	2.58	2.70	3.92	7.51	6.22	5.35	4.05	5.81
Sudan	0.66	1.34	2.63	1.37	1.56	0.89	2.38	2.45	3.20	5.53
Nigeria	0.42	-0.43	0.81	1.36	3.11	2.21	3.66	4.68	3.04	5.53
Algeria	1.82	2.72	3.46	2.60	2.89	3.87	2.44	4.39	3.84	3.97
Tunisia	-0.94	-0.31	2.23	2.54	4.01	2.21	3.91	4.78	3.39	3.63
Cote d'lvoire	1.03	0.85	1.73	0.98	1.23	1.03	1.04	1.89	2.56	3.54

Source: ODA Korea, http://www.odakorea.go.kr/eng.result.RegionCountry_Overview.do

Along with the atmosphere of geopolitical rivalry surrounding South Korea, Korean aid to Sub-Saharan Africa is aimed at seeking potential markets (Darracq and Neville 2014; Kim 2019). As such, the cooperation between Tanzania and Korea has continued and deepened as the late prime minister of Korea and his Tanzanian counterpart agreed to strengthen economic and business cooperation between the two countries. According to Yonhap News Agency (2018), the late Prime Minister of Korea, Lee Nak-yon,[27] visited Tanzania in July 2018, and addressed the Korean government's plan for continuous assistance to Tanzanian development while requesting the Tanzanian government's support for Korean firms in Tanzania. The basic direction of the Korean government's assistance plan for Tanzania is pictured in the country partnership strategy (CPS) for Tanzania.[28] This plan suggests that the overall aim of the Korean government's assistance to Tanzania is the sustainable development of the Tanzanian economy. Moreover, as Figure 3-6 shows, one of the main purposes of the Korean government is to deliver the developmental experience of Korea to Tanzania. In 2016, Korean government renewed the CPS for Tanzania, which includes four focused fields—water and hygiene, transportation, education, and energy—of assistance.

[27]Lee served as the Prime Minister from May 2017 to Jan 2020
[28]See figure 3-6

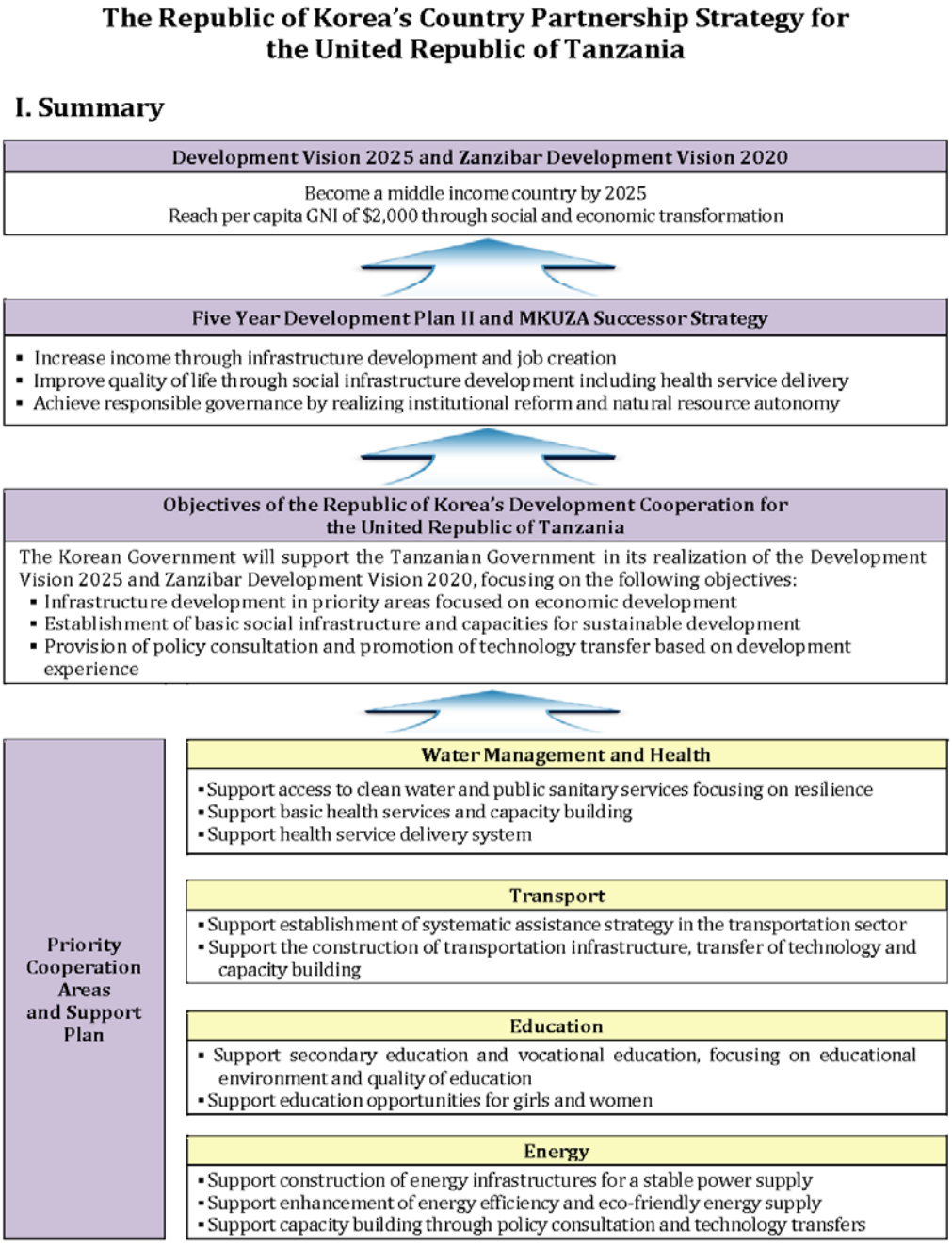

Figure 3-6. The South Korean Government's Basic Assistance Plan for Tanzania

Source: Country Partnership Strategy (CPS) for the United Republic of Tanzania, December 2016

3-2-3. Summary

The bilateral US-Korea and Tanzania-Korea relationships suggest that the S&T relationship between Korea and the two other countries is closely related to the political and economic relationship between countries. Historically, geopolitical issues such as U.S. competition against communist countries during the Cold War and South Korea's competition against North Korea after the Korean War initiated unidirectional economic and technological support from the US to Korea and from Korea to Tanzania. In other words, in contrast to the US-Korea relationship, which began with U.S. aid to Korea, the Tanzania-Korea relationship developed through Korean aid to Tanzania. In conjunction with Korea's economic development, the US has since terminated aid to Korea, and in 2010, Korea emerged as a new donor country of ODA by joining the DAC of the OECD (Choi 2011). In particular, studies have asserted that the termination of financial aid has transitioned the US-Korea relationship from a unidirectional—from the US to Korea—to a bidirectional bond (STEPI 1999, Wagner et al. 2003).

With the beginning of Korean aid to other countries, Tanzania has been one of the largest recipient countries. To expand its political and economic relationship with Tanzania, the Korean government has emphasized the Korean experience of transition from a recipient to a donor of ODA. Relevant studies have suggested the new role of Korea as a bridge between countries with varying levels of development (Choi 2011; Kalinowski and Cho 2012; Mawdsley 2012; Kim et al. 2013). Even though developmental stages may vary, the bilateral relationships between Korea and these two other countries show that both the US-Korea and the Tanzania-Korea relationships have continuously grown. The last section of this chapter explores the disparities found within

the collaborative projects between Korea and two other countries based on interviews with a Korean professor in my case study.

3-3. Case study: How are Collaborative Projects Unequal?

Along with the uneven development of GDP, GNI, S&T, and the bilateral relationships, my case study suggests that collaborative projects between Korea-US and Korea-Tanzania are unequal in terms of emotional and physical accessibility, as well as educational level in S&T. According to Professor A on the Korean research team, visiting Tanzania for collaboration projects is more difficult than visiting the US for collaboration projects; this is because emotionally, students tend to feel distant from Tanzania, as they are less familiar with African countries compared to the US, and because physically, there is no direct flight to Tanzania from Korea.[29] To put it differently, for a Korean research team, emotional and physical distance hinders their access to Tanzanian research team. Professor A also said, "Our team invites students from Tanzania to pursue their Master's or doctoral degree, but the invited students often find it difficult to follow education in our university because the [systems] of higher education in S&T are different in Korea and Tanzania."[30] In other words, disparity in S&T education hampers the collaboration between Korean and Tanzanian research teams.

[29]Interviewed on April 25, 2018.
[30]Interviewed on April 25, 2018. Professor A borrowed the saying from Tanzanian students studied in his laboratory and told me that the higher-education level in Korea is higher than that of Tanzania. With regard to the same issue, a Tanzanian local staff member who has completed his BA in the engineering school in Tanzania told me that working with the Korean research team is challenging because his study focused on theory and the research with the Korean team focus on the practical experiments.

Despite difficulties in physical and emotional accessibility and educational level, Professor A said that the Korean team conducted the collaborative project with a Tanzanian university for long-term educational purposes. For Korean Professor A, the collaboration with a Tanzanian university is costly in terms of research funding and time. Assuming that the Korean research team spends the same amount of funding and time, according to Professor A, his research team would produce more publications by not participating in the joint research project with the Tanzanian team. However, the collaboration incorporates volunteer activities in rural Tanzania, which helps Korean professors and students learn how to apply their technology to varied environments. Professor A mentioned, “Hands-on engineering experience in rural Tanzania is very unique, and ‘energy’ is a hot topic these days. By conducting projects on energy-related technology in Tanzania, our team gains a reputation. This ‘reputation’ helps us conduct other related R&D projects in the future.” Thus, for the Korean team, research collaboration with Tanzania is meaningful in the long term rather than the short term.

With the U.S. research team, the Korean team shares human resources, publications, and doctoral degrees. There has been one doctoral student from the Korean team who pursued a dual degree since Korean and U.S. colleges signed a memorandum of understanding (MOU) in 2014 (MOU 2014). To earn the dual degree, the doctoral student from a Korean team visited the U.S. laboratory for a year, joined research projects, and published co-authored journal papers. In addition, both professors in the Korean and U.S. universities were committee members for the student’s doctoral dissertation. Professor A used expressions such as “collaboration” and “together” more often when mentioning the collaborative project with the U.S. team than in describing the

project with the Tanzanian team. Such expressions show that Professor A emphasizes an equal relationship between Korean and U.S. research team.

In a similar vein, using expressions that reflected equal and unequal relationships, Professor A said, "Universities, professors, and students question the effectiveness of collaboration with the Tanzanian universities, but we do not doubt the necessity of collaboration with the U.S. universities. We all agree with the idea that our university needs to be more international, and conducting joint projects or establishing joint degree programs with U.S. universities benefits us."[31] At the same time, Professor A claimed that collaboration with the U.S. team would be more effective if both teams conducted more similar research projects. A said:

> While our team focuses on experiments, the U.S. team studies computational simulation. Experiments and simulations are complementary, but our research projects do not overlap with the U.S. team that much. I think the collaboration would be more effective if we conducted similar research projects.[32]

That is, regardless of the evident research results, Professor A insisted that insufficient similarities between the U.S. and Korean teams hamper further collaboration.

Whereas the shortage of similar research projects between the U.S. and Korean teams discourages additional collaboration, the uneven number of visiting students reflects an uneven relationship between the U.S. and Korean universities. Since the establishment of the dual degree program, only Korean students pursued dual degrees and

[31]Interviewed on April 25, 2018.
[32]Interviewed on April 25, 2018.

visited U.S. laboratories.[33] As of October 2020, none of the U.S. students had pursued the dual degree program nor visited the Korean university.[34] The uneven number of visiting students is not limited to the institutional level. Nationally, more than 52,000 Korean students enrolled in U.S. universities while approximately 1,400 U.S. students entered Korea with student visa.[35] Table 3-3 shows the number of foreign students in U.S. universities and their country of origin. As the table indicates, Korea is the country that sends the third most students to the US, following China and India. Table 3-4 represents the number of U.S. visitors holding a student visa in Korea from 2010 to 2018. While the number of U.S. students has continuously increased from 616 in 2010 to 1,430 in 2018, the total number of students is far less than the number of Korean students in the US.

[33]As of Spring 2020, three Korean students (two from the research team I visited and one from other team) wanted to apply for the dual degree program and two of them successfully joined the program.
[34]As for the reason why none of the U.S. students visited the Korean university, Professor F on the U.S. team suggested the lack of awareness among students in the U.S. university (email communication, October15, 2020).
[35]Open Doors Data (WENR, https://wenr.wes.org/2018/10/education-in-south-korea), Korean Statistical Information Service

Table 3-3. Number of International Students in U.S. Universities in 2018 and 2019

Rank	Place of Origin	Number of Students	% of Total
1	China	369,548	33.7
2	India	202,014	18.4
3	South Korea	52,250	4.8
4	Saudi Arabia	37,080	3.4
5	Canada	26,122	2.4
6	Vietnam	24,392	2.2
7	Taiwan	23,369	2.1

Source: Institute of International Education. (2019). "Top 25 Places of Origin of International Students, 2012/13-2018/19." Open Doors Report on International Educational Exchange. Retrieved from http://www.iie.org/opendoors

Table 3-4. Number of U.S. Visitors Holding a Student Visa in Korea

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018
Number of Student Visa Holders	616	738	792	873	1,015	1,006	1,090	1,339	1,430

Source: International Migration Statistics, Korean Statistical Information Service (http://kosis.kr/statHtml/statHtml.do?orgId=101&tblId=DT_1B28023&conn_path=I2)

3-4. Summary

To examine the national contexts of Korea, the US, and Tanzania, this chapter presented annual trends in S&T expenditures, GDP, GNI, and the tertiary level school enrollment of each country, as well as bilateral relationships between Korea and two other countries and an individual interview with a Korean professor participating in the collaborative research projects with U.S. and Tanzanian partners. Statistical data, such as R&D expenditure per GDP, GDP per capita, GNI per capita, and the tertiary level school enrollment rate, suggested that the three countries are in varying levels of development in terms of S&T, economics, and education. The bilateral relationships between Korea and the two other countries initiated with ODA and continuously developed. In particular, the US-Korea relationship began with U.S. aid to Korea, whereas the Tanzania-Korea relationship started with Korean aid to Tanzania. Accompanied by the economic growth of Korea, the US-Korea relationship has since moved from unidirectional to bidirectional, and Korea has shifted from being a recipient to becoming a donor of ODA. Moreover, the Korean government has stressed the Korean experience of development to expand its bilateral relationship with Tanzania.

An interview with a Korean professor who participated in collaborative research projects with both the US and Tanzania showed that the merits and demerits of collaboration may vary by country. According to this professor, emotional and physical distance, as well as educational disparity, hinders collaboration with Tanzanian partners, while long-term educational goals promote collaboration. The professor also asserted that the shortage of similar research projects hampers collaboration with U.S. partners even though the collaboration produces research results, such as the publication of journal

articles. In addition, the number of Korean students in the US and U.S. students in Korea suggests the uneven relationship between U.S. and Korean universities. While this chapter of the study showed the varied contexts of each country, the next chapter of the dissertation examines the history of technology involved in these collaborative research projects and the emergence of collaboration within the Korean research team.

CHAPTER 4. HISTORY OF TECHNOLOGY AND THE EMERGENCE OF THE COLLABORATION

Prior to the presentation of the analyses of the findings, this chapter offers the context of the collaborative research projects by examining the history and policies of related technology and the emergence of collaborative projects. With the US research team, the Korean research team focused on the advancement of nanoparticle technologies and with the Tanzanian research team, the Korean team concentrated on the development of solar power systems. Section 4-1 discusses the technological history of nanoparticles, nanotechnology policies in Korea and in the US, technological history of solar photovoltaics, and solar energy policies in Korea and in Tanzania. Section 4-2 discusses the three research sites in Korea, the US, and Tanzania and how two collaborative projects (the US-Korea and Tanzania-Korea projects) emerged through the Korean research team.

4-1. History of Technology

4-1-1. Technological history of nanoparticles

The Korean research team collaborated with the US research team in the field of nanoparticle-deposition systems. In particular, a Ph.D. student on the Korean team was pursuing a dual degree by conducting a joint research project with the US team and completing a doctoral dissertation on nanoparticle deposition. The collaboration was complementary, because the student focused on practical, hands-on experiments while on the Korean research team and examined computational modeling with the US research

team (NAS 2011). With both Korean and US academic advisors, the student developed a laser and a computational model that laminates nano-sized alumina or copper particles on a polymer substrate, which is used for robots or sensors. Figure 4-1 shows the machine and computational model developed for the joint degree program. To better understand the technology involved in this example of collaboration between Korea and the US, the following discussion explores the technical history of nanoparticles and related S&T policies in the respective countries.

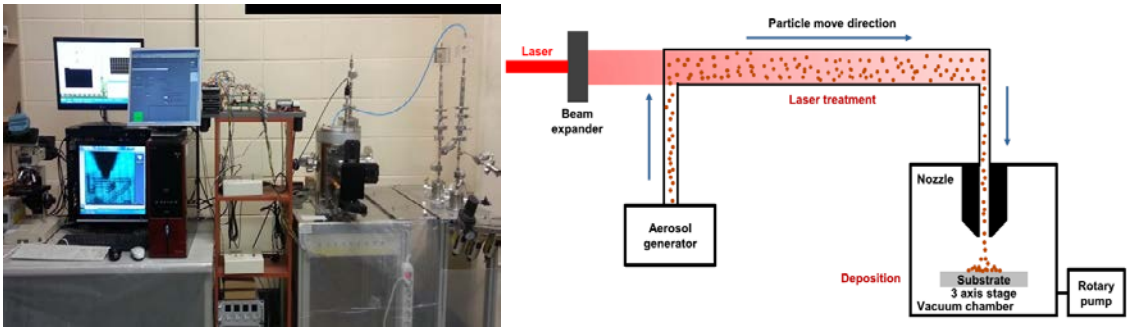

Figure 4-1. Aerodynamically Focused Nanoparticle Printer (left) and Computationally Modelled System Configuration (right) used for the Joint Research Project between the US and Korean Research Team

Source: IDIM (2018), Song et al. (2018)

The definition of *nanoparticles* varies by material, field, and application. However, Yokoyama (2012:5) suggested that nanoparticles often refer to ultrafine particles ranging from one to one-hundred nanometers. According to the author, one nanometer is one billionth of one meter, one millionth of one millimeter, or one thousandth of one micrometer. The technical history of these ultrafine particles traces back to the development of quantum mechanics by Max Planck in 1900 (Newton 2009).

Planck founded the field of quantum mechanics in 1900 by solving a nettlesome scientific puzzle regarding blackbody radiation that he had investigated with his colleagues (Newton 2009). Guo and Tan (2009:4) asserted that Max Planck "found he had to assume that total energy was not a continuous spectrum but rather made up of discrete energy elements—quanta of energy—an unprecedented step for quantum mechanics." In other words, the finding of ultrafine elements in the form of subatomic particles that constitute energy led to the discovery of nanoparticles. At first, the idea that radiation is composed of a series of subatomic particles instead of a continuous energy spectrum was a deviant idea amongst physicists (Guo and Tan 2009). Despite experimental data, some physicists were skeptical of Plank's theory (Guo and Tan 2009).

The physics community began to accept Planck's theory after Albert Einstein applied the theory to the photoelectric effect and proposed the "quantum theory of light" (Guo and Tan 2009:4). Based on Einstein's theory, Bohr explained the structure of hydrogen atoms, and De Broglie proved the existence of a wave and particle duality in every material (Bohr 1934; Bohm 1951; De Broglie 1990; Peres 2006). Later, Schrodinger successfully applied wave mechanics to solve puzzles surrounding the behavior of hydrogen atoms (Schrodinger 1982). In addition to Schrodinger's application, Guo and Tan (2009) claimed that, Heisenberg's uncertainty principle is the core of quantum mechanics. According to the uncertainty principle, the position and the momentum of a particle is not measurable at the same time, because the measuring process disturbs the momentum of a particle (Heisenberg 1949). Heisenberg discovered that the statistical pattern of electrons is more important than their physical status, and the

foundation of a statistical definition transitioned the paradigm of quantum mechanics in physics (Guo and Tan 2009).

4-1-2. Nanotechnology policies in Korea

While nanoparticles have a long scientific history, national S&T policies regarding nanotechnologies in both Korea and the US emerged only at the beginning of the twenty-first century. According to Lee (2005), the technological potential of nanotechnology together with the initiation of the National Nanotechnology Initiative (NNI) in the US fostered massive global investment in nanotechnologies. As for the technological potential, Lee (2005) suggested that nanoscience not only enables technologies at the atomic, molecular, and supramolecular levels, but it also enhances the functions of conventional technologies. In line with this global boom in nanotechnology, in July 2001 the Korean government began promoting nanotechnologies by constructing "the first general development plan for nanotechnology [*Je il-gi nano kisul jonghap baljeon gyehoek*]." The plan was later modified in 2005 and 2011. In general, the 2001 plan envisioned the development of infrastructures and cutting-edge technologies for the next ten years (*Nano kisul jonghap baljeon gyehoek* 2001). Figure 4-2 illustrates the road map of the Korean government's policy to promote the development of nanotechnologies in Korea.

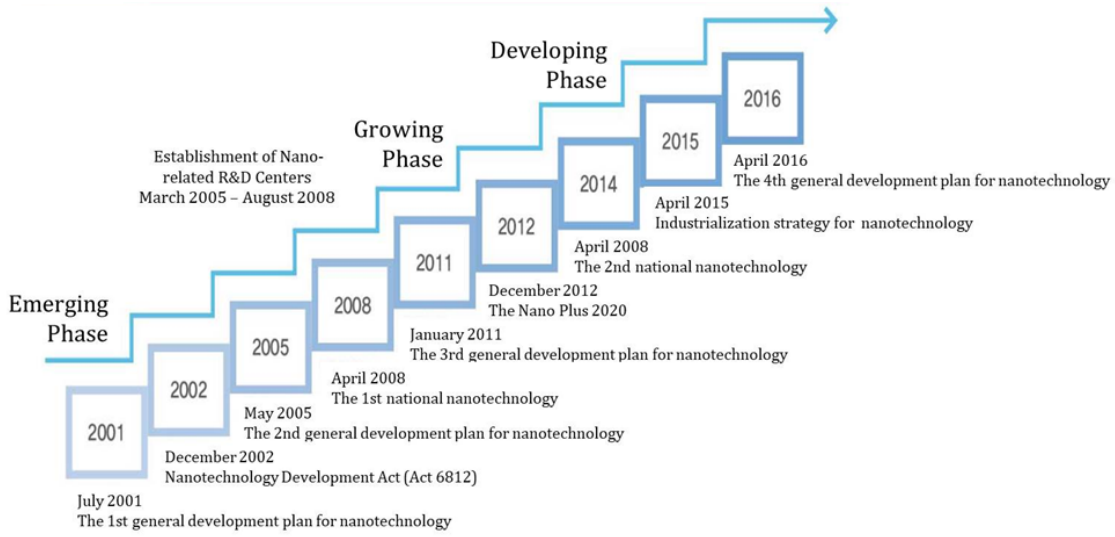

Figure 4-2. The Road Map of the Nanotechnology Policies in Korea

Source: Korea Nanotechnology Annual 2017:29

As shown in the road map, 2001–2008 was the emerging phase, 2011–2012 was the growing phase, and 2014–2016 was the developing phase for Korean nanotechnology policies. During the emerging phase, the Korean government established major R&D centers associated with nanotechnologies, including the National NanoFab Center, Korea Advanced NanoFab Center, Korea Printed Electronic Center, and the Nano Convergence Practical Application Center (Korea Nanotechnology Annual 2017). During the growing phase, the Korean government announced a national S&T strategy called "Nano Plus 2020," which promoted businesses related to nanotechnologies by investing 930 billion KRW (approximately 7,716 million USD[36]) by 2020.[37] Following the foundational efforts during the emerging and growing phases, the Korean government focused on industrialization during the developing phase that began in 2014.

[36]1 USD = 1,200 KRW

[37]Ministry of Knowledge Economy (MKE). Press Release. December 4, 2012.

Along with government-driven policies promoting the development of nanotechnology, since 2001 the Korean government has increased the amount of investment in nanotechnology-related R&D, infrastructure, and human resources (HR). In general and as discussed in Section 3-1 (Trends of R&D Expenditure, GDP, GNI, and School Enrollment Rate), Korea has invested a relatively larger percentage of its GDP on the development of S&T since the end of the twentieth century. Amongst the various fields of S&T, the increase in financial investment in nanotechnology suggests that the Korean government was encouraging the rapid development of relevant technologies. Accordingly, Table 4-1 presents the annual investment in the field of nanotechnologies in Korea. Compared to 2001, the amount of investment increased more than six times in 2017 and reached approximately 648 billion KRW (approximately 537.7 million USD[38]).

With strong support from the government, the number of nano-related patents has increased annually by 20%, and Korea occupied 5.5% of the global patents in the field of nanotechnology from 2001 to 2017 (Korea Nanotechnology Annual 2017). According to the Korea Nanotechnology Annual (2017), this is the third largest proportion after the US (55.9%) and Japan (13%). Table 4-2 represents the accumulated number of patents related to nanotechnologies in the US, Japan, Korea, Germany, Taiwan, France, China, The Netherlands, the UK, Canada, and other countries from 2011 to 2017. In addition, during these years, the number of relevant journal-article publications in Korea increased from 1,334 to 9,022, or by an overall ratio of 12.7% annually. Table 4-3 indicates the number of nanotechnology related journal articles published from 2001 to 2017 in the top six countries, which are China, the US, Japan, Germany, Korea, and India.

[38]1 USD = 1,200 KRW

Table 4-1. The Annual Investment of Nanotechnologies in Korea

(Unit: 0.1 billion Won)

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total
R&D	955	1,589	1,644	1,631	1,700	1,933	2,045	1,964	2,303	2,075	2,178	2,623	4,692	4,596	4,649	4,259	5,635	4,6471
Infra*	30	456	626	702	840	688	610	526	110	224	226	181	210	206	227	395	335	6,592
HR*	67	76	105	147	136	162	159	139	130	128	130	30	343	511	581	527	513	3,884
Total	1052	2121	2375	2480	266	2783	2814	2629	2543	2427	2534	2834	5245	5313	5457	5181	6483	56,947

Source: Korea Nanotechnology Annual 2017

*Herein, Infra refers infrastructure and HR refers human resources

Table 4-2. The Accumulated Number of Nanotechnology Related Patents in Selected Countries from 2011 to 2017

Country	Number of Patents	Share	Average Annual Increasing Rate (2001-2017)	Average Annual Increasing Rate (2013-2017)
USA	81,994	55.9%	5.9%	4.3%
Japan	19,101	13.0%	3.6%	1.9%
South Korea	8,064	5.5%	20.0%	15.1%
Germany	7,394	5.0%	4.0%	5.8%
Taiwan	4,905	3.3%	14.5%	9.5%
France	4,370	3.0%	3.2%	4.6%
China	3,503	2.4%	34.0%	21.4%
The Netherlands	2,251	1.5%	10.5%	5.6%
UK	2,154	1.5%	5.9%	7.6%
Canada	1,788	1.2%	4.3%	4.2%
Others	1,427	1.0%	9.3%	9.9%
Total	146,760	100.0%	6.6%	6.2%

Source: Korea Nanotechnology Annual 2017:145-146

Table 4-3. The Number of Nanotechnology Related Journal Articles Published in Selected Countries from 2001 to 2017

Country	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total	CAGR
China	2,899	3,496	4,699	5,906	7,928	10,116	12,067	14,591	16,557	18,874	23,175	26,787	32,360	39,310	45,086	48,268	54,781	366,900	20.2%
USA	6,703	7,709	8,785	10,072	11,790	13,180	14,405	15,507	16,148	17,815	19,176	20,297	21,509	22,668	23,203	24,089	24,297	277,353	8.4%
Japan	4,086	4,586	4,820	5,259	5,459	5,874	6,121	6,388	6,445	6,444	6,857	6,865	7,139	7,382	7,258	7,598	7,467	106,048	3.8%
Germany	3,301	3,618	3,640	4,046	4,422	4,950	5,270	5,656	5,898	6,504	7,086	7,151	7,545	8,040	8,254	8,675	8,568	102,624	6.1%
S. Korea	1,334	1,416	1,909	2,359	2,672	3,142	3,455	4,301	4,700	5,357	6,416	7,002	7,651	8,283	8,935	9,223	9,022	87,177	12.7%
India	731	788	1,005	1,217	1,440	1,879	2,412	2,982	3,401	4,107	5,077	5,543	7,101	8,748	9,507	10,377	10,807	77,122	18.3%

Source: Korea Nanotechnology Annual 2017:128

4-1-3. Nanotechnology policies in the US

In a similar vein as the Korean government, the US government has encouraged the advancement of nanotechnology since the beginning of the twenty-first century. In 2000, the US government began the NNI,[39] which was supported by the 21st Century Nanotechnology Research and Development Act in 2003. As shown in Figure 4-3, the NNI incorporates more than 20 departments and agencies, such as the Department of Commerce (DOC), the Department of Defense (DOD), the Department of Energy (DOE), and NASA. The NNI supports various federal departments, independent agencies, and commissions that jointly conduct R&D on nanotechnologies. The main goals of the NNI are the following:

- advance a world-class nanotechnology research and development program;
- foster the transfer of new technologies into products for commercial and public benefit;
- develop and sustain educational resources, a skilled workforce, and a dynamic infrastructure and toolset to advance nanotechnology; and
- support responsible development of nanotechnology (NNCO 2017:2).

In addition, by offering a framework for diverse institutions, the NNI engages academia, governments, and industries that pursue R&D in the field of nanotechnology.

Under the auspices of the NNI, the US federal government has invested more than 23 billion USD into nanotechnology R&D and commercialization (NNISP 2016). The National Nanotechnology Initiative Strategic Plan (NNISP 2016) indicated that each NNI member agency directly funds nanotechnology R&D while the NNI summarizes each investment through the publication of annual reports. By providing a framework that brings various agencies and experts together, the NNI supports an efficient use of

[39]See National Nanotechnology Initiative (https://www.nano.gov/about-nni)

resources related to the development of nanotechnology (NNISP 2016). Moreover, the NNI has played a vital role in promoting various national priorities such as national security, economic development, and job creation in the US (Korea Nanotechnology Annual 2017).

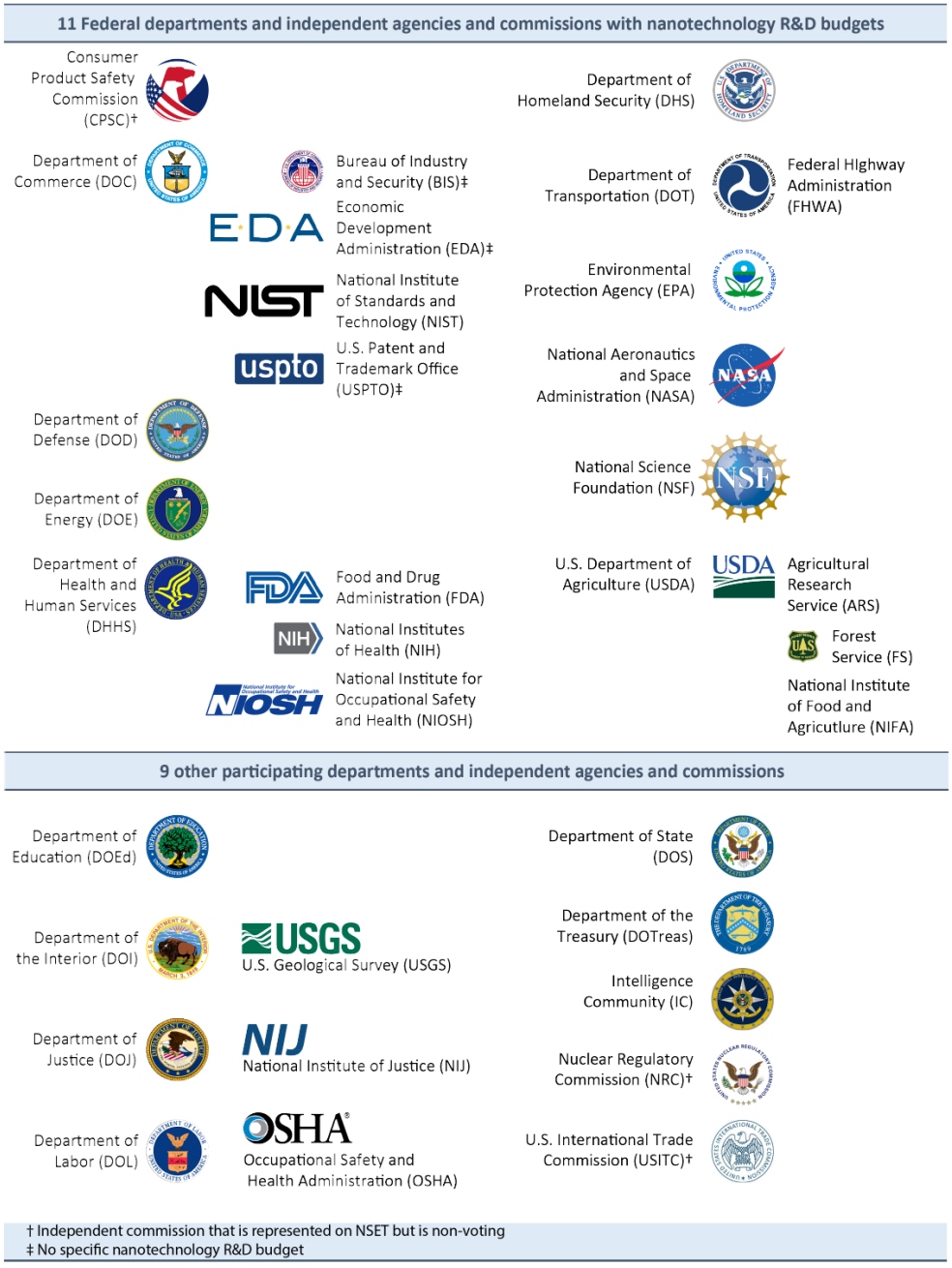

Figure 4-3. Departments, Agencies, and Commissions of the NNI
Source: 2016 National Nanotechnology Initiative Strategic Plan

4-1-4. Technological history of solar photovoltaics

As discussed in the previous section, the U.S. and Korean research teams focused on the development of nanotechnology that was being promoted by both national governments. At the same time, in collaboration with Tanzanian engineers, technicians, and local people, the Korean research team built a 40kW solar power plant and developed a solar-power-monitoring system in rural Tanzania where the national grid power network did not yet reach. The collaboration between the Tanzanian and Korean team was in the form of technical assistance that involved a beneficial partnership between universities (NAS 2011). In short, the Korean research team helped the Tanzanian team build the solar energy system by providing cutting-edge technologies, and the Tanzanian team helped the Korean team by solving relevant technical issues in a local village. To better understand the technology involved in the collaboration between Korea and Tanzania, this section examines the technological principles and the history of solar cells as well as the related S&T policies in Korea and Tanzania.

Figure 4-4 illustrates the structure and the principle of a solar cell, which produces electricity using electrodes made of semi-conductors. A solar power system mainly consists of a solar cell, a battery, and a power converter. The solar cell, which is composed of the conjuncture of an N-type (negative) semi-conductor and a P-type (positive) semi-conductor absorbs solar light and produces particles containing positive holes and electrons (New and Renewable Energy 2016). While electrons move to the N-type semi-conductor, positive holes move to the P-type semi-conductor, and this potential difference produces an electric current (New and Renewable Energy 2016).

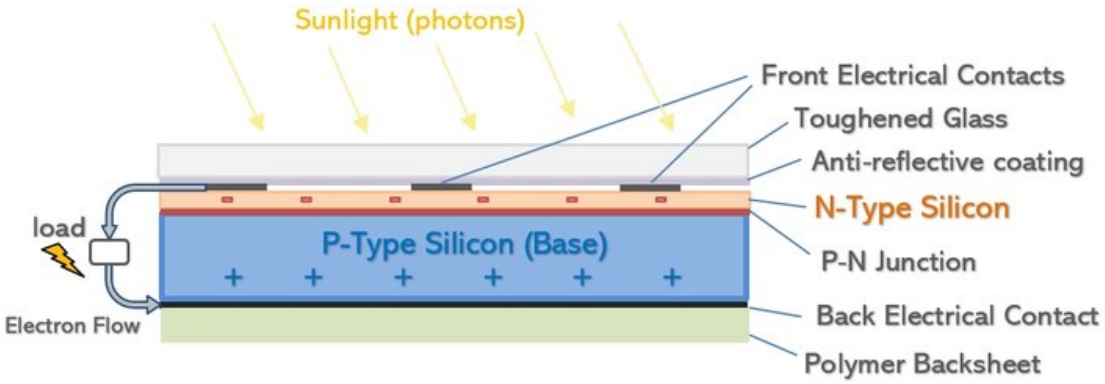

Figure 4-4. The Structure and the Principle of the Solar Cell Module

Source: Svarc, Jason. July 31, 2018. "Solar PV Cell Construction" *Clean Energy Reviews*. Accessed July 23, 2020 (https://www.cleanenergyreviews.info/blog/solar-pv-cell-construction)

The technological history of solar cells traces back to Edmond Becquerel's discovery of the photovoltaic effect in 1839 (Fraas 2014, Hoang 2017). According to Hoang (2017), in 1905 Albert Einstein was the first scientist to adequately explain the photovoltaic effect in his theory of the photoelectric effect. In 1883, Charles Fritts invented the first solar cells, which were made of selenium wafers. Hoang (2017) noted that the materials used for solar cells changed from selenium to silicon by the early twentieth century. While silicon was inexpensive, the manufacturing cost for silicon photovoltaic cells was expensive because of impurities and material-loss (Khalifa et al. 2012). In addition, the first-generation solar cells were inefficient and converted less than 1% of the solar energy to electricity (Butti and Perlin 1980). Until the 1950s, photovoltaic cells were considered invaluable in the commercial market (Butti and Perlin 1980).

4-1-5. Solar energy policies in Korea

The history of solar energy technology in South Korea dates back to 1978 when the Korean government launched a long-term R&D plan for solar energy (Park 2016). According to Park (2016), the Korean government's plan was provoked by the first oil shock in 1973 and solar energy policies of developed countries. The 1978–2000 long-term policy plan regarding the development of solar energy in Korea consisted of four stages that aimed to commercialize solar power generation. The first stage, 1978–1981, targeted establishing sample solar housings; the second stage, 1982–1986, aimed to commercialize solar heating systems and develop solar cells; the third stage, 1987–1991, focused on the commercialization of solar cells and the development of photovoltaic systems; and the final stage, 1992–2000, highlighted the commercialization and test runs of solar power generation plants (Park 2016).[40]

Table 4-4. The 1978–2000 Long-term R&D Plan for Solar Energy in Korea

Phase	Period	Plan
1st Stage	1978–81	Establishment of solar housings
2nd Stage	1982–86	Commercialization of solar heating Development of solar cells
3rd Stage	1987–91	Commercialization of solar cells Development of photovoltaic system
4th Stage	1992–2000	Commercialization of solar power generation Test runs of solar power generation

Source: The Korea Research Institute of Solar Energy [*Taeyang Energy Yeonguso*] (1978)

[40]See Table 4-4 (The table is created based on the source)

While the plan was the first long-term R&D policy that discussed new and renewable energy in Korea, it failed during the first stage (Park 2016). To promote the use of solar energy in the beginning, the Korean government released low-interest loans for building solar housings (Park 2016). However, according to Park (2016), the government-driven policies for promoting the implementation of solar housing became stagnant when the government reduced loan benefits and technological problems occurred. Park (2016) claimed that impetuous actions driven by the Korean government resulted in the failure of the plan. In particular, the Korean government's sense of urgency fostered unprepared construction companies to rush into the solar housing businesses without systematic and standardized supervision (Park 2016). Moreover, from a technological standpoint, Korean companies relied on foreign products by importing and localizing solar energy collectors developed by foreign countries, such as the US and Japan (Park 2016). According to Binz et al. (2017), from 1965 to 1990, the US and Japan were the two pioneering countries in the field of photovoltaic manufacturing.

In 1987, the Korean government established another long-term R&D plan for the development of solar power technology and launched relevant R&D projects for national research institutes, industries, and universities (Jang 1990). As presented in Table 4-5, the 1988–2001 plan prioritized the localization and development of solar cell technologies. The plan consisted of three stages that focused on the localization, standardization, and optimization of relevant technologies. Table 4-6 shows the number of government-funded R&D projects regarding solar energy in 1989 and 1990. From 1989 to 1990, the number of related R&D projects increased from 17 to 23, and the level of financial support from the Korean government almost doubled from 1.3 billion KRW to 2.4 billion KRW (Jang 1990). Despite the failure of the new and renewable energy policies driven by the first

long-term plan, the Korean government continuously supported the development of solar cell technologies.

Table 4-5. The 1988–2001 Long-term R&D Plan for Solar Energy in Korea

Phase	Period	Plan
1st Stage	1988–91	• Development of low-price materials and the manufacturing process for Si solar cells • Development of materials and manufacturing process for amorphous or compound solar cells • Development of the high-efficiency peripheral devices • Localization of the measuring technologies for solar power systems • Application of the ~100kW solar energy generator
2nd Stage	1992–96	• Localization of manufacturing technologies for amorphous or compound solar cells • Development of low-price and highly efficient solar cells • Development of the auto-control system • Application of the 100kW~ solar energy generator • Standardization of solar energy systems
3rd Stage	1997–2001	• Development of low-price and highly efficient solar cells • Application of the MW solar energy generator

Source: Jang (1990:8)

Table 4-6. Government-Funded Solar Energy R&D Projects in Korea in 1989 and 1990

Year	Cross-national Projects			Domestic Projects		Total	
	Number of Projects	Government Grants (million KRW)	Participating Institutions	Number of Projects	Government Grants (million KRW)	Number of Projects	Government Grants (million KRW)
1989	13	1,213	Enterprises (5*), Government-funded Research Institutions (3), Universities (3)	4	98	17	1,311
1990	18	2,257	Enterprises (6), Government-funded Research Institutions (4), Universities (4)	5	173	23	2,430
Total	31	3,470	(Note: 11 projects continued from 1989)	9	271	40	3,741

*The number of participating institutions

Source: Jang (1990:9)

With government-driven financial support policies for the solar energy market, solar energy facilities in Korea have increased since 2001. In addition, as solar power supply increased to 1GW in 2015, Korea became the seventh largest supplier in the global solar energy market (New and Renewable Energy 2016). Table 4-7 illustrates the annual energy production from 2004 to 2015. The annual production of solar energy in Korea gradually increased from 2,468 Toe in 2004 to 849,379 Toe in 2015. At the same time, the output of solar energy in Korea rose from 9,872 MWh to 3,979,159 MWh. Even though Korea was a late-comer in the field of solar technology, the number of patents issued to

Korean inventors regarding solar photovoltaics has dramatically increased since mid-2000s, and Korea shared 11% of global patenting in the field of photovoltaics from 2006 to 2012 (Binz et al. 2017). Although solar energy occupied only a small portion of the total energy used in Korea,[41] the increase of solar energy production and relevant patents suggests the advance of solar energy technologies in Korea.

[41] 0.7% in 2015, See Table 4-8

Table 4-7. The Annual Production and Output of Solar Energy in Korea from 2004 to 2015

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Production (Toe)	2,468	3,600	7,756	15,325	61,128	121,731	166,152	197,198	237,543	344,451	547,430	849,379
Output (MWh)	9,872	14,399	31,022	71,279	284,315	566,191	772,801	917,198	1,103,227	1,605,182	2,556,300	3,979,159

Source: New and Renewable Energy Center, Korea Energy Agency. 2016. *2015 New and New and Renewable Energy Statistic*

Table 4-8. The Annual Energy Output in Korea from 2004 to 2015

Unit: GWh

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Total Energy Output	342,148	364,639	381,180	426,647	422,355	433,603	474,660	501,527	532,191	543,098	546,249	560,974
New and Renewable Energy Output	4,534	3,950	3,899	4,395	4,227	4,617	5,889	17,346	19,498	21,438	26,882	37,079
Solar Energy Output	9.9	14.4	31.0	71.3	284	566	773	917	1,103	1,605	2,556	3,979

Source: New and Renewable Energy Center, Korea Energy Agency. 2016. *2015 New and New and Renewable Energy Statistics*

4-1-6. Solar energy policies in Tanzania

Similarly to Korea, solar energy in Tanzania developed from government-driven energy policies beginning in the 1970s. According to Hansen et al. (2015), the Tanzanian government began financing the photovoltaic electrification of rural schools, churches, and health centers in the 1970s. Since the late 1990s, the consumer market for the photovoltaic industry in Tanzania has expanded as a result of the industry's expansion in Kenya (Hansen et al. 2015). In 2005, the Tanzanian government provided tax benefits for installing solar energy systems by exempting value added tax (VAT) and reducing import duties (Hansen et al. 2015). However, despite the highest techno-economic capability, solar energy produces only a small portion of the energy in Tanzania (Aly et al. 2019).

As for the amount of solar energy generation in Tanzania, Aly et al. (2019:46) report, "between 2009–10 and 2016–17, the government of Tanzania allocated nearly two billion USD to energy access, of which 98% was targeted to grid-based energy projects." In short, solar energy occupies less than 2% of the total energy generation in Tanzania. The main resources of energy production in Tanzania are hydroelectricity and natural gas (Ministry of Finance and Planning 2016). Aly et al. (2019) have suggested that institutional, financial, and technological barriers have prevented the further development of solar energy system in Tanzania. However, to diversify its energy resources, the Tanzanian government plans to increase the solar energy generation (Ministry of Finance and Planning 2016). In addition, international donors have been actively supporting the expansion of solar energy in Tanzania (Aly et al. 2019). For example, in 2007 through the Tanzania Energy Development and

Access Project (TEDAP), the World Bank offered a subsidy to companies to develop solar technologies, implement mini-grids, and test new models (World Bank 2007).

4-1-7. Summary

To better understand technologies involved in the collaborative projects, this part of the dissertation examined the history of nanotechnology and solar technologies as well as relevant S&T policies. With the US research team, the Korean research team has focused on the advancement of nanoparticle technologies, and with the Tanzanian research team, the Korean team has concentrated on the development of solar power systems. While the scientific history of nanoparticles began with the development of quantum mechanics by Max Planck and was then further advanced by other scientists since 1900, the history of solar cells started with the discovery of the photovoltaic effect by Edmond Becquerel, and they were subsequently developed by other scientists since 1839. The relevant S&T policies in Korea, the US, and Tanzania suggest that each government has promoted the development of nanoparticle and solar technologies. The following section introduces three research sites in Korea, the US, and Tanzania and then explains how two collaborative projects (the US-Korea and Tanzania-Korea) emerged in the Korean research team.

4-2. The Emergence of the Collaboration

4-2-1. Three sites and two projects

To understand the relationship between the structure and agency of knowledge sharing and production in a bridge country and its partners from countries where the S&T emerges and develops unevenly, I followed two projects of a Korean mechanical engineering team. Since 2017, the mechanical engineering team in a

Korean national university has been conducting one project with a US university and another with a Tanzanian university. To follow these two projects, I conducted my fieldwork in three laboratories in Korea, Tanzania, and the US, and the first location of my fieldwork was the Korean laboratory. Despite the fact that I was the only social scientist in the laboratory, the beginning of my stay with the Korean team proceeded smoothly, as it seemed there were organized processes in place to support short-term visits by field researchers.[42]

On January 5, 2018, my journey to assess these two collaborative projects began as I attended a preparation meeting held by the Korean team for their one-week trip to Tanzania for collaboration. The meeting offered general information about the joint research project and the local environment, and the attendees included students on the Korean team as well as undergraduate and graduate students from other universities who were joining the trip for volunteer purposes.[43] I introduced myself to the attendees during this meeting, and afterward, a professor with the Korean team introduced me to two student interns who were in charge of the administrative procedure and the laboratory tour for new-comers. After explaining how to access the laboratories and resources, the students guided me to the desk that I could use during my fieldwork. In essence, this meeting was the starting point of immersing myself in the lives of the Korean students on the Korean research team. Then, my first

[42]During my fieldwork, I found out that short-term visitors (mostly from the engineering field) were common in the Korean research team, and my visit fitted into the category of "visiting graduate student."

[43]Later during my fieldwork in the Korean team, I found out that students in the Korean team are required to join one of trips to developing countries before the completion of their degrees. This requirement was implicit and exited only in this particular team. For students from other universities who joined the trip voluntarily, the trip was not mandatory, but they joined the trip for personal experience, which they believe will be beneficial for their future career.

engagement with the U.S. and Tanzanian teams occurred by following students on the Korean research team when they had meetings with their research partners. The following sections introduce the three laboratories and the emergence of two collaborative research projects that are examined in this study.

4-2-2. Laboratory description: Korea

The Korean research team that I selected was a manufacturing research team in a national university in Korea. As of September 2020, the Korean team consisted of 35 people, including one director (professor), one visiting professor, four postdoctoral researchers, eleven Ph.D. students, eleven M.S. students, six student interns, and one administrative staff member.[44] Of thirty-five personnel, 14% are international and 11% are female. Historically, the team was launched in 2003 when the director began working in the current university. Since then, the first two M.S. students graduated in 2006 and one Ph.D. student graduated in 2009. Over ten years, 62 M.S. students and 33 Ph.D. students graduated from the Korean research team including 12 international and four female students. The research team has developed its own formal and informal cultures such as office hours, duties, and rewards. Once students begin working in the laboratory, they are given a laboratory handbook that the first cohort of students created in consultation with the director.

[44]See Table 4-9. The number of people working in the Korean laboratory is floating between thirty and forty because of short-term visitors, post-doctoral researchers, internships, military service, and graduation.

Table 4-9. Human Resources in the Korean Research Team (as of 22 September, 2020)

	Professor	Visiting Professor	Post-doc	Ph.D.	M.S.	Intern	Administrator	Total
Number	1	1	4	11	11	6	1	35

The Korean research team was comprised of sub-teams working in five major areas of research, including energy devices, smart robotics, micro- and nano-systems, biomedical devices, and appropriate technologies. Within the five sub-groups, the team mainly developed cost- or time-saving machineries or devices using automation and optimization processes. For example, one of the research projects at the time aimed to develop faster and more precise printing of nano-scale metallic powders on flexible devices, such as robotic sensors. The U.S. and Korean teams collaborated on research focusing on a laser that laminates metallic nanoparticles such as alumina or copper on a flexible substrate that is made of polymer. This flexible device is applied to nano-sized robots or sensors by controlling actuators. For the joint research project, the U.S. team focused on the development of simulation programs through computational modeling while the Korean team focused on the development of an end product through testing and manufacturing.

The Korean team also developed solar power plants and monitoring systems in rural Tanzania. In particular, the team implemented a 40kW solar power plant in a rural village of Tanzania, and established a monitoring system to control the flow of generated electricity. While half of the electricity was expected to be used for the

community, the other half was distributed to local residents to install three fluorescent lights in and outside of their houses.[45] Moreover, the team controlled and monitored the electricity generated by the solar plant using a smart meter they developed. Using this meter, the team, local technical staff, and the residents know how much electricity is used in each house. The research team planned to measure the impact of their technology in the village using these electricity use trends. For the village residents, the smart meter enables them to pay their bill based on their real use.

The Korean research team held three types of weekly meetings—laboratory, group, and individual—that allowed formal communication between the professors and graduate students. The meetings lasted approximately 30–90 minutes. In the weekly laboratory meeting (also called "lab seminar"), researchers took turns presenting their on-going research. Since there were about thirty presenters including postdoctoral researchers and graduate students, the researchers presented once a month in the lab seminar.[46] During their presentation, the researchers also introduced books that inspire creative thinking. In group meetings, each group of graduate students met with a professor and discussed the group's on-going project.[47] For example, the smart-robotics group discussed the development of manufacturing processes for a mesoscale actuator to power artificial muscle movements. In

[45]Before the research team set up the smart meter, the monthly cost of electricity distributed to local residents was 10,000TZS (4USD). The cost to customers was decided by the local community that collected and used electricity fee for the operation of the solar power plant in the village. 46 households in the village used the electricity offered by the research team.
[46]The number of researchers working in the Korean laboratory is floating because of short-term visitors, internships, military service, and graduation.
[47]The Korean research team consists of energy devices group, smart-robotics group, micro- and nano-systems group, biomedical devices group, and appropriate technologies group.

individual meetings, professors consulted each student about their own research. The team used Google Calendar to check the professors' schedules and set up meetings. Major funding sources of the laboratory were the NRF and private companies.

4-2-3. Laboratory description: US

As of October 2020, the professor in the U.S. research team had mentored over 70 graduate and undergraduate students for research, including 16 female and 8 minority students. Currently, the team consists of eleven people including one director (professor), six Ph.D. students, and four B.S. students.[48] Of the ten students, four are international and one is female. The U.S. team's research focused on developing new modeling and simulation mechanisms and tools for multiscale systems. The team also developed innovative modeling and simulation mechanisms to optimize large-scale production processes. In particular, the team conducted research on multiscale simulations, manufacturing process planning, risk assessment, and data analyses. One of the research projects was to design an optimized manufacturing process for 3D-printing factories. In contrast with the Korean research team that consisted of five sub-groups, there was no sub-group in the U.S. team, because each student worked on a different project. The U.S. team held weekly meetings, during which each student presented their on-going research. Major funding sources were government agencies including NSF and private companies.

[48]See Table 4-10.

Table 4-10. Human Resources in the U.S. Research Team (as of October, 2020)

	Professor	Ph.D.	B.S.	Total
Number	1	6	4	11

4-2-4. Laboratory description: Tanzania

The Tanzanian research team began in 2017 when the Korean Ministry of Science and ICT established a local appropriate technology center in a government-funded S&T university in Tanzania. Since 2015, the Korean Ministry of Science and ICT has established local appropriate technology centers in developing countries, and the centers focus on sustainable development in the countries by operating S&T programs needed in the recipient countries. The research topics of the Tanzanian team focused on new and renewable energy, agriculture, water, education, and business. As for new and renewable energy, the center built a 40kW solar energy generator and a monitoring system in a rural Tanzanian village where access to energy was low. The research on agriculture focused on the development of a storage and packaging system using the village's solar energy generator. The study regarding water centered on the development of irrigation systems for agriculture. By combining education and business, the center has mentored local start-up companies to launch and sustain themselves.

The Korean government sponsored the center with two billion KRW

(approximately 1,667,000 USD[49]) over a period of three years and nine months, until 2020. The annual budget of the center is five hundred million KRW (approximately 417,000 USD[50]). Physically, the center is located in a government-funded S&T university in Tanzania that has provided administrative offices, research space, and engineering equipment as well as professional networks between the Tanzanian and Korean universities. In addition, the research space and equipment in the Tanzanian university were originally funded by the World Bank. Therefore, while the Korean government initiated the appropriate technology center, the initiation would not have emerged without the land from the government-funded Tanzanian university and the buildings and equipment from the World Bank.

The Tanzanian research team consisted of eleven people including one Korean local director, two Tanzanian professors, four engineering/technical staff members, and four administrative staff members, who were members of a participating social enterprise and technicians of the "Techno Peace Corps (TPC)" project sponsored by the Korea International Cooperation Agency (KOICA).[51] Figure 4-5 represents the map of human resources of the collaborative project between the Tanzanian and Korean research teams. As the composition of human resources shows, the universities as well as the governments and social enterprises supported managerial, administrative, research, and technical personnel for the collaborative projects. In the joint research project between the Tanzanian and Korean research teams, social enterprises have provided mentoring in business skills from the initial stage.

[49]1USD=1,200KRW
[50]1USD=1,200KRW
[51]See Table 4-11.

In collaboration with the Korean research team, the Tanzanian team implemented a solar power plant and distributed electricity to a local village in rural Tanzania (IPP media.com 2018a).[52] In January 2018, the joint research team began operating the power plant for 46 households in the village. Of the generated 40kW, 20kW was used in the power plant center for the benefit of the whole local community, and the remaining 20kW was distributed evenly to each house. Even before the power plant came online, local residents chose a reasonable price for electricity and appointed local staff members, such as a manager and a bookkeeper, to work for the power plant center. Until the joint research team established the smart-meter, the monthly price of electricity distributed to local residents was 10,000 TZS (4 USD). After providing the electricity generated from solar power, the use of electricity in the village increased. According to the joint research team, the amount of electrical use in the village increased more than three times from 114.87kW/h in July 2018 to 388.37kW/h in March 2019.[53]

Table 4-11. Human Resources in the Tanzanian Research Team (as of Spring 2020)

	Korean local director	Professor	Engineer/Technician	Administrator	Total
Number	1	2	4	4	11

[52]Also see Figure 4-6.
[53]Also see Wang et al. 2020. "Low-cost far-field wireless electrical load monitoring system applied in an off-grid rural area of Tanzania" *Sustainable Cities and Society*, 59(2020):1-13.

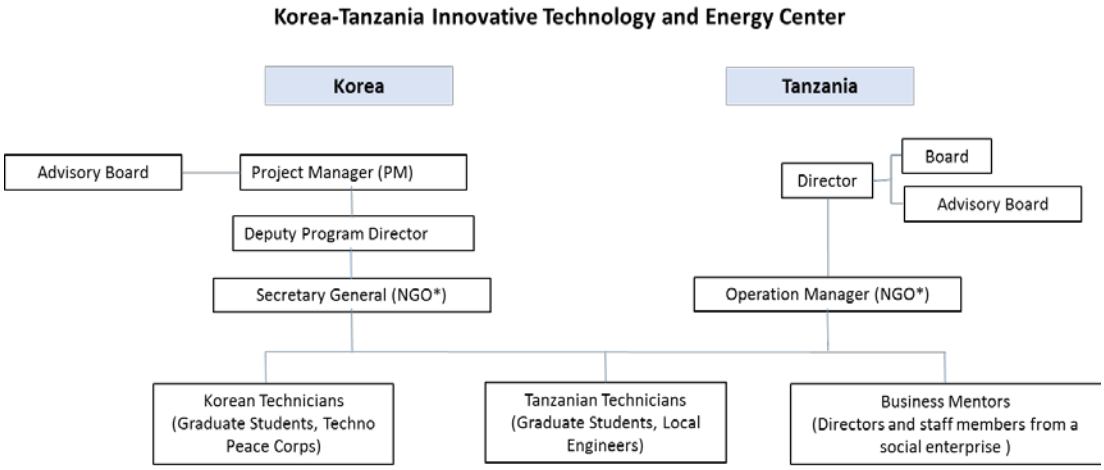

Figure 4-5. The Map of Human Resources in the Korea-Tanzania Joint Research Team

Source: ITEC (2018), Participant Observation

*Non-Government Organization (NGO) participating in the project later has merged with a social enterprise

Figure 4-6. The Photo of Rural Village in Tanzania where the Korean Research Team Built Solar Power Plant and its Monitoring System in Collaboration with the Tanzanian Research Team

4-2-5. Emergence of the US-Korea collaborative project

In 2015, the U.S. and Korean universities established a joint Ph.D. program in the field of mechanical engineering.[54] Students who wished to join the dual degree program were required to undergo the same application process as the students who apply for the conventional graduate program. For example, students from the Korean university must submit the online graduate application, transcripts, letters of recommendation, and test scores to the U.S. university. The Korean research team began collaborating with the U.S. research team by sending a graduate student (Student B) to the U.S. laboratory to work with a co-advisor. According to Student B, studying for the GRE and TOEFL tests required additional work for the Korean students. Student B said, "After finishing my work in the laboratory, I had to take private classes to study for the GRE and TOEFL, and taking these tests was not easy." Once Student B was accepted to the dual degree program, the PIs established a joint research project through email communication.[55]

The joint project ended in 2020. The aim of the project was to develop breakthrough computational models and the production of less expensive and non-toxic printing machines throughout the dual degree program. Korean Student B worked in the U.S. laboratory for eleven months from January to November 2016, and during the visit to the US research team, B studied the computational model of

[54]Applying the dual degree program is optional for students. While two students from the Korean university joined the program, none of the students from the US university have applied for the program.

[55]Before PIs establish a joint research project, student B sent the areas of research interest to the mechanical engineering department in the US university, and then the US PI contacted student B saying that their research team is interested in collaboration.

nanoparticle deposition process. After returning to work with the Korean research team, Student B continued working on hands-on experiments to research the same process. In February 2019, Student B completed a Ph.D. degree and began working as a postdoctoral fellow in the Korean laboratory.

The joint project was funded by the Brain Korea 21 Plus project, which provides funding for international collaborative research projects in Korean universities by supporting graduate-level human resources in science and engineering. Moreover, during the stay in the US, Student B worked as a research assistant on a research project funded by the NSF. As of March 2021, the U.S. team had published two co-authored journal papers in collaboration with the Korean research team (Song et al. 2018, Song et al. 2020). One journal paper and one book are also in the process of publication (IDIM 2018).

4-2-6. Emergence of the Tanzania-Korea collaborative project

In 2017, the Korean and Tanzanian universities launched a joint research center, which aims to develop, educate, and commercialize innovative appropriate technologies that are suitable for the Tanzanian environment. To promote technology sharing between Korea and developing countries, the Korean Ministry of Science and ICT has established local science and technology centers in universities in Cambodia, Laos, Nepal, Tanzania, Ethiopia, and Vietnam since 2015.[56] A Korea-Tanzania joint research center is one of them. The NRF approved the collaborative project in April 2017, and the Korean and the Tanzanian teams implemented a research center in a Tanzanian government-funded university. The project was scheduled to end in 2020.

[56]See https://www.gnsat.or.kr/index.do

The joint research center emerged with the launching of a new project by the Korean government and the gathering of people from various sectors. After the establishment of local appropriate technology centers in Cambodia, Laos, and Nepal, the Korean Ministry of Science and ICT released a similar project to build and operate an appropriate center in a Tanzanian university. A social enterprise that had been providing IT education and solar panels in rural Tanzania considered applying for the project. Director C from the social enterprise said,

> I've been providing IT education in Tanzania for four years. Even before providing IT education, my husband [Director D] and I came to Tanzania once a year and opened empowerment centers. That is, in 2013, 2014, and 2015 we implemented empowerment centers that offer small buildings equipped with solar panel and computers. Local people can start a business in the center. The first center in Dodoma was very successful. We provided a center with six rooms and computers. Local people began six businesses there. After we successfully built three centers in different sites, one of the churches in Tanzania requested me to build a center near their church. The church sponsored building an empowerment center, and introduced me to people who work in the field of appropriate technologies. This is the background story of how we considered applying for the project to operate an appropriate center in a Tanzanian university.[57]

As for the application of the project, the ministry requested the inclusion of a project manager (PM) from a university in Korea. Therefore, Director C contacted a professor in a national university in Korea to form a consortium. Director C added:

> Because we are a small company, the donor of the project [the Korean government] has asked us to apply for the project as a consortium. To be a consortium, we need a PM from a university. … A professor who has been working in the field of appropriate technology introduced us to the current PM [Professor A] of our project. … An NGO helped us

[57]Interviewed on June 22, 2018

> write the proposal when we applied for the project. Then we merged with the NGO and built the Korean branch of our company.[58]

According to Director C, staff from an NGO, which later merged with the social enterprise, also participated from the stage of writing proposals. Thus, the existent social ties among people who served in the field of appropriate technology in academia, in the industry, and in NGOs created other connections and gathered people for the new project.

Participants from a Tanzanian university were identified through co-organizing the conference and signing an MOU (IPP Media.com 2018b, ITEC 2018). According to a professor from a Tanzanian university,

> I think it is through the MOU that our Korean partners came and visited us. We met, and we had some discussion. Now they have a concrete project, you know, without projects, an MOU is just a piece of paper. When they visited me, it was amazing that, you know, the kind of things they were talking about fit very well with what we have been doing.[59]

The MOU was signed in December 2017 when professors and students from Korea visited Tanzania before the official initiation of the project (ITEC 2018). The above excerpt shows that signing the MOU between the Korean and Tanzanian university was the initial step for operating the appropriate technology center in Tanzania. However, the signing of a MOU did not occur out of the previous engagement. Prior to signing the MOU, both universities co-organized the International Conference on Energy and Sustainability (ICES) 2017 that was held in Tanzania in August 2017 (ITEC 2018). Based on social networks created during the conference, both partners signed the MOU and began the project.

[58]Interviewed on June 22, 2018
[59]Interviewed on June 29, 2018

To implement a solar power system, including a power center, telegraph poles, and electric wires, in the local village, the joint research team collaborated with local residents and technicians. For instance, residents built the village power plant center that was equipped with solar power panels on the roof as well as batteries.[60] The panels and batteries were implemented by the research team in collaboration with local technicians.[61] Local technicians also installed telegraph poles and electric wires that connect the power center and local houses. While local villagers built the center as volunteers, local technicians were hired by the joint research team.[62] As of March 2021, the Tanzanian and Korean research teams published three co-authored journal papers (Wang et al. 2020; Wang et al. 2020; Wang et al. 2021). In addition, since spring 2019, one Tanzanian student (Student P) who was recommended by the Tanzanian research team joined the Korean research team. As a doctoral student on the Korean research team, Student P participated on the collaborative projects between Tanzania and Korea.

[60]See Figure 4-7
[61]Local technicians were called “fundi”.
[62]The research team hired five local technicians.

Figure 4-7. The Photograph of Local Residents in the Village Building the Power Plant Center

4-2-7. Summary

This section described the three research sites and two collaborative projects examined for this study. The Korean laboratory consisted of thirty-five people studying energy devices, smart robotics, micro- and nano-systems, biomedical devices, and appropriate technologies. The U.S. laboratory was comprised of eleven people studying new modeling, simulation mechanisms, and multiscale systems. The Tanzanian laboratory consisted of eleven people, including a Korean local director, Tanzanian professor, and both Tanzanian and Korean staff members. The Tanzanian team worked to develop new and renewable energy, agriculture, water, education, and business. The collaborative project between the Korean and U.S. laboratories focused on the development of computational models and the production of advanced printing machines through a dual degree program. The joint project between the Korean and Tanzanian laboratories centered on developing, educating, and commercializing innovative appropriate technologies through a joint research center. The next chapter considers a theoretical framework to analyze the findings from this research.

CHAPTER 5. FINDINGS AND ANALYSES

A close examination of the international research collaboration of Korea with the US and Tanzania reveals the structure-agency relationship in cross-national knowledge sharing and production. By analyzing the findings in relation to Bourdieu's concepts of symbolic powers and habitus, this chapter examines the relationship between structure and agency. According to Bourdieu, while individuals organize society, symbolic powers such as economic, social, and cultural capitals limit individual activities within society. Economic capital means material assets that convert into money, social capital refers to resources that are connected to relationships, and cultural capital indicates values, skills, knowledge, and tastes that are embodied in people (Bourdieu 1986). Bourdieu (1986) suggests that capital is a form of social structure, referring to institutionalized rules and regulations of society, and consists of both accumulated labor of individuals and their social energy. For example, accumulated living conditions of individuals since their early childhood are related to the production of economic capital such as property rights (Bourdieu 1986).

While social structures determine individual or group agency through symbolic powers, agents influence the social structures through habitus. Here, habitus is defined as a social space generated historically through interactions of objective probabilities (structure) and subject aspirations (agency), it is flexible, and this flexibility strongly structures the rules and regulations of society (Bourdieu 2012). The findings in this study suggest that the process of cross-national knowledge-sharing and -production is habitus where both symbolic powers and individual agency

shape each other. Particularly, the analyses show that individual agency is essential for conducting international research collaborations between countries with varied economic, social, and cultural capitals.

5-1. Structural Discrepancies at a National Level

As examined in Chapter 3, the national contexts of Korea, the US, and Tanzania are varied; thus, structural discrepancies influence the flow of economic, social, and cultural capitals as well as cross-national knowledge sharing and production between countries. Historically, state actors have utilized the financial capital and S&T at a national level to fulfill their political and economic interests. For example, to occupy the dominant position against communist power in the region of North-East Asia, the US offered a significant amount of ODA, including technological aid, to South Korea during the Cold War era. Moreover, the competition between South and North Korea as well as the competition among China, Japan, and Korea spurred the Korean government to increase the amount of ODA and technology sharing to African countries, especially, Tanzania.

The economic growth of Korea and the country's transition from a recipient to a donor country of ODA has shifted the US-Korea relationship from unidirectional to bidirectional. In line with this change as evidenced in this study, both the U.S. and Korean governments were able to invest economic capital to support a doctoral student who pursued a dual degree program at a U.S. and a Korean university. By contrast, in the case of a joint research project between Tanzania and Korea, the project depended on economic capital provided by the Korean government. Therefore, the flow of economic capital was unidirectional from Korea to Tanzania. In addition,

the flow of social capital between the US and Korea denotes structural discrepancy between the two countries. For example, far more Korean students are studying in the US than U.S. students studying in Korea. In a similar vein, only students from the Korean university have pursued the dual degree program and no U.S. students have visited the Korean university.

As for cultural capital, Korea is the only country that has experienced the transition from a recipient to a donor country of ODA amongst the fifteen largest donors in DAC. The Korean government has also stressed its unique experience of changing its national developmental status to expand the bilateral relationship with Tanzania. After the transition, the Korean government included "technology sharing" in the key agenda for the development of national S&T and established local science and technology centers, including a Korea-Tanzania joint research center. During the project, the context of transition as cultural capital encouraged actors to initiate and sustain the cross-national knowledge sharing and production.

5-2. Relationship Diagram

To better understand the analyses, this section briefly introduces the people involved in the findings.[63] Professor A is a Korean PI of the Korea-US and Korea-Tanzania projects. Professor F is a U.S. professor who directed the Korea-US project and was a co-advisor of Student B. As a Ph.D. student on the Korean research team, Student B pursued a dual degree program between the Korean and the U.S. university. In a partial fulfillment of the dual degree program, Student B joined the U.S. research team of Professor F. Director D is a Korean local director on the Tanzanian research

[63]See Figure 5-1.

team, and Professors G and L are Tanzanian professors who joined the Korea-Tanzania joint research project. Professor F is a mutual friend of Professor A and Director D. Director C, wife of Director D, is a director of a social enterprise involved in the Korea-Tanzania project. Students J and N on the Korean research team worked for the joint research project between Korea and Tanzania. The project also involved Tanzanian Staff Member K and Korean Staff Member M, who worked on the Tanzanian team.

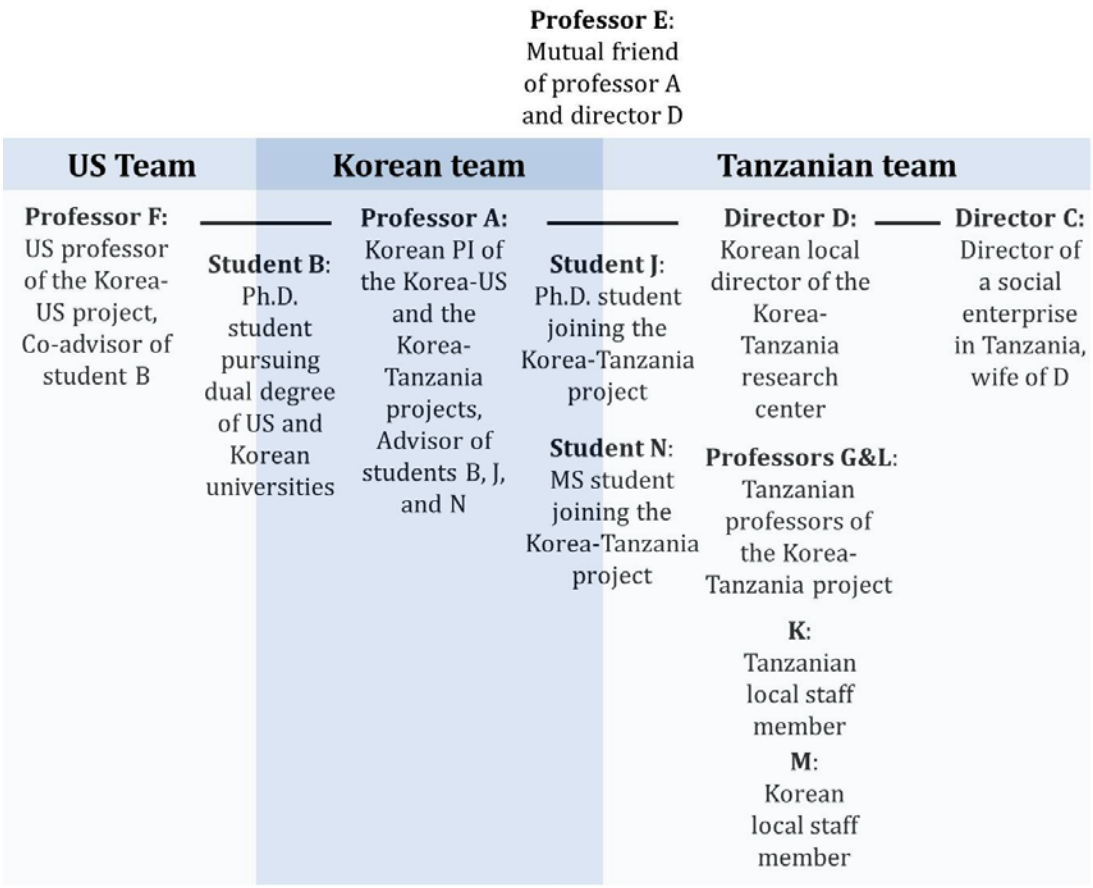

Figure 5-1. The Relationship Diagram of People in the Analyses

5-3. Economic Capital

5-3-1. Financial supports and limits

The economic capital for the joint research project between the Korean and Tanzanian university emerged along with the national science and technology agenda. After transitioning from a recipient to a donor country of ODA in 2010, the Korean government differentiated itself from existing donors by emphasizing the developmental experience of science and technology in Korea (Kim and Gray 2016). Accordingly, in August 2011 the term “technology sharing” occurred in the key agenda for the development of national science and technology in Korea. In 2012, the Korean government developed the Korean model of Official Development Aid (ODA) that included technology sharing with developing countries. In brief, as an emerging donor the Korean government stressed the need of Korean aid by conceptualizing its model of ODA.

To implement the national science and technology agenda, since 2015 the Korean Ministry of Science and ICT has established local science and technology centers in universities in Cambodia, Laos, Nepal, Tanzania, Ethiopia, and Vietnam. The Korean research team, in collaboration with the Tanzanian team, implemented a joint research center that is operated at a Tanzanian government-funded university. From April 2017 to December 2020, the Korean Ministry of Science and ICT contributed two billion KRW (approximately 1.8 million USD) that provided research space, including land and buildings, to a Tanzanian university. The human resources of the center consisted of one Korean PI, one local Korean director, two Tanzanian professors, one director from a social enterprise, four Korean local staff members, and

four Tanzanian staff members.[64] In addition to the staff members, five Korean graduate students advised by the Korean PI participated in the research programs organized by the center.

As economic capital, financial support from the Korean government both promoted and constrained individuals. As a means of promotion, financial support from the Korean government initiated the center and attracted individuals who are interested in the field. At the same time, financial limits have constrained individual activities in the center. Local Director D said:

> I think this collaboration will be more successful if we conduct a number of projects that are needed in Tanzania. For example, using electricity generated by the solar power plant, we may store onions harvested in the village and increase the profit. Also, we may build a fishery so that the villagers can sell fish.[65]

In other words, Director D believes that the sustainable development of the center requires combining different projects rather than focusing on one project that implements a solar power system in the local village. He also said, "500 million KRW for one year is not enough for conducting several projects that bring the needed synergetic effect." To overcome the financial limits that constrain activities of the center, Director D claimed that he has been actively applying for other sources of funding from various sponsors, including the other university in the US as a collaborator.

As for the financial sustainability of the project, Director D argued that in addition to the multiple external sources, the center must generate profit for at least 50%

[64]The number of staff members includes members from an NGO that later merged with a social enterprise.
[65]Interviewed on June 23, 2018.

of the operation costs to sustain it after 2020. This argument implies that the involvement of market value contributes to the sustainable development of the joint research project between Tanzania and Korea. Moreover, as the inclusion of the social enterprise suggests, financial sustainability of the project was one of the top priorities for the Korean government and participants. In a similar vein, both the Korean and Tanzanian participants acknowledged the importance of acquiring financial support from the Tanzanian government for sustaining the center after the termination of the financial support from the Korean government. In brief, the findings regarding the limit of economic capital imply that the inclusion of multiple donors, industrial actors, and the local government contribute to the sustainable development of donor-supported projects in developing countries.

5-3-2. Opportunity

Whereas economic capital both promotes and constrains individuals conducting international research collaboration, such collaborative projects provide opportunities to obtain research funding. According to Professor F, one of the advantages of conducting international research collaboration is opportunity to acquire additional research funding. Professor F said, “Meaning, new research funding. Actually [Professor A] and I wrote a research proposal together for [the project funded by] one of the companies.”[66] Irrespective of the acceptance of the proposal, Professor F emphasized that he and Professor A were eligible to apply for new projects because of their collaboration. Professor F added, “Collaborations provide advantages. If you only focus on your own theme, you may lose the insights. … [To solve] new problems, you have to have meaningful collaboration to get a new

[66]Interviewed on July 21, 2018.

idea quickly." In other words, collaboration provides new opportunities by complementing what is lacking in the research team.

5-3-3. Economic Capital Summary

The Tanzania-Korea research collaboration shows that economic capital both promotes and constrains cross-national knowledge sharing and production. For example, while financial support from the Korean government initiated the joint research project and attracted relevant human resources, limited financial resources hindered the further development of the project. At the same time, conducting international research collaboration generates opportunities to expand economic capital. In the case of the collaborative project between the US and Korea, the collaboration provided opportunities for Professors A and F to apply for another research grants. Even though the application was not successful at that time, Professor F argued that the opportunity resulted from the collaboration. In brief, whereas economic capital influences knowledge sharing and production, knowledge sharing and production also affects the influx of economic capital. The following section discusses social capital related to the collaborative projects.

5-4. Social Capital

5-4-1. Intertwined networks

From the view point of the participants, social capital played a vital role for the emergence of the collaborative project between Tanzania and Korea. Korean Professor A mentioned that many professors, students, and missionaries come to his office to discuss their project with developing countries because his research team has been collaborating with developing countries for several years. These relationships of

connectivity are important, because they eventually convert to resources that are needed for cross-national knowledge sharing and production. That is, as the team is well-known for conducting projects with developing countries, any information regarding developing countries, such as relevant research projects, businesses, and human resources, is available in his office.

The human resources of the collaborative project between Korea and Tanzania were also gathered through social capital. For example, Korean Local Director D said that he met Korean Professor A through a mutual friend, Professor E. In 2013, Korean Local Director D built a small solar panel on the roof of the local building in Tanzania and established six micro businesses such as a restaurant, a hair shop, and a copy center upon the request from a missionary. The owners were local people, and their businesses composed the first business center Director D and his wife Director C[67] helped develop in Tanzania. Their solar panel and business center were on the local news, and people contacted and asked them to develop the second and third business centers in other locations.

When Director C, who managed the social enterprise, went to Korea and gave a speech about their work, Korean Professor E told her that the Korean government was looking for a specialist to serve as a Korean local director in Africa. Director C introduced her husband Director D to Professor E, who then connected Director D, who was interested in building solar panels in Tanzania, with Korean Professor A, who was interested in collaborating with developing countries. Although Professor A and Director D did not know each other, they had a number of mutual friends.

[67]C is a director of the social enterprise that joined the collaborative project between Tanzania and Korea.

According to Director D, "other friends told me that [Professor A] is really a decent and hard-working person. That's why I decided to apply for this project and work with him."[68] This example speaks to the importance of social capital.

Additionally, social capital played a vital role when Korean Professor A and Korean Local Director D searched for their Tanzanian counterpart. During the interview, Tanzanian Professor G asserted that he knows many Korean researchers because he had pursued his doctoral degree in Korea. As for how he joined the collaborative project, Tanzanian Professor G explained,

> I went for my Ph.D. in South Korea. That's how I had connections with many South Koreans. There are many. [I have connections with] professors at H University [where I pursued my doctoral degree]. And I studied public health at J University [in Korea as well]. So I have a lot of connections in Korea. When I returned to Tanzania, [I started a] company and met [people from a Korean] social enterprise. They asked if they could visit me [and] talk. [During the talk] we saw the potentials for collaborations [and] that's how our relationship grew step by step until the establishment of the Tanzania-Korea joint research center.[69]

Professor G claimed that people who he knew in Korea have connections with Directors C (social enterprise director) and D (Korean local director), and Korean Professor A. Therefore, an intertwined social network, as social capital, brought together both Tanzanian and Korean participants for the implementation of the joint research project.

5-4-2. Collaboration for expanding views of students and professors

As shown in the case of the joint research project between Tanzania and Korea, social capital promoted international research collaboration by connecting

[68]Interviewed on June 23, 2018.
[69]People from the social enterprise that Tanzanian professor G met participated in the collaborative project between Tanzania and Korea. Interviewed on June 27, 2018.

participants residing in various places. At the same time, Professor F, who worked on the U.S. research team, asserted that accumulated social capital expands views of students and professors, and he remarked:

> One of the main purposes for [Korean Student B] to join the joint PhD program was to expand the view or perspective of students as well as professors [in both Korea and the US]. [Student B] works in both [the] US and [Korea]. [Working in both countries provides the student] different perspectives in terms of different settings in universities, organizations, [and] research groups. Researchers need the constant inspiration, [and] that's why researchers attend conferences. This provides the setting for students to accelerate the idea exchanging process. To join this kind of PhD program is to experience such kind of a setting. Students have both styles. It is good for idea exchange. Of course [it is also] good for professors' perspectives. So it's kind of give and take. Students learn from professors, and at the same time, professors learn from students. Students can be good bridges for each other to learn research perspectives. I'm certain for those years, I learnt something from [Student B]. Of course, from [Student B] and from [Professor A]. It's good collaboration.[70]

The above passage suggests that Korean Student B, who pursued the dual degree program, provided inspiration to U.S. students and professors. In addition, U.S. Professor F claimed that he conducts research collaboration because accumulated social capital helps to acquire broader perspectives, such as different ways of thinking, which result from different experiences. According to Professor F, these broader perspectives are crucial for the advancement of knowledge.

Relatedly, Korean Student B also argued that international research collaboration promotes creative thinking. According to Student B, conducting joint research projects is advantageous, because ideas expand through examining the study from different standpoints. B said:

[70]Interviewed on July 21, 2018.

> When it comes to research, [Korean Professor A] and I tend to think in a similar direction because we are on the same research team. But, [U.S. Professor F] introduces me to a totally different way of thinking from a varied perspective. For example, while [Korean Professor A] and I only thought about sensors and actuators for application, [U.S. Professor F] suggested different examples such as flexible electronics.[71]

This excerpt from Korean Student B, together with the comments from U.S. Professor F, suggests that the dual degree program between the U.S. and Korean universities broadened the views of Student B, professors, and other students. In this case, as Professor F claimed, the joint research project between US and Korea promoted the advancement of knowledge through social capital.

5-4-3. International collaboration and networking

In a similar vein with Professor F, who is on the U.S. research team, Professor G on the Tanzanian research team asserted that international research collaboration strengthens social networks that transform to economic capital. Professor G explained:

> Because their country is developed, [Korean researchers] have advanced knowledge, better skills, facilities, and networks, strong networks. [Through] my collaboration, I joined other networks, and [Korean researchers] introduce me like "oh we work with [someone] in Tanzania." Then, their network becomes my network. I get a lot of benefits. Some people did not give me money directly, but they have given me connections, which was turned out to be very useful. [This is not the Korean example, but one of my connections helped me to receive] the DFID (the Department for International Development) grant [from the U.K. government]. It's [approximately 454,000 USD]. So if someone can help you with that kind of network, what [else] do you need? You don't need money. Do you?[72]

[71]Interviewed on May 21, 2018.
[72]Interviewed on June 27, 2018.

For Tanzanian Professor G, conducting international research collaboration is advantageous, because it advances knowledge and provides social capital. In particular, Professor G stated that international collaborations have provided him with social capital (social networks), which later helped him to receive economic capital through a research grant. This example is aligned with Bourdieu's theory regarding the conversion of social capital into economic capital.

5-4-4.Time difference hampers the accumulation of social capital

As the interviews with Tanzanian Professor G and U.S. Professor F imply, research collaboration expands the views and networks of participants through social capital. However, the time difference that occurred during the international research collaboration hampered the accumulation of social capital and thus the exchange of knowledge and ideas among the researchers. With regard to time difference, Professor F said, "In collaboration, [which necessitates] constant meetings, time zones could be major barriers to exchange the idea."[73] He added that sending emails or having virtual conferences may reduce the barrier, but in-depth discussion is more than necessary to create new ideas. This finding echoes the arguments in previous studies regarding structural barriers (Lee and Bozeman 2005; Ponomariov and Boardman 2010; Kalawong 2016). According to Lee and Bozeman (2005), high communication costs that result from physical distances among researchers hinder collaborations.

Based on interviews with 60 U.S. academic faculty researchers, Bozeman et al. (2016) also suggested that effective communication leads to "good collaboration." Herein, "good collaboration" refers to research collaboration that the interviewees consider effective, and this does not necessarily relate to the number of publications

[73]Interviewed on July 21, 2018.

or patents or the level of economic capital. According to U.S. Professor F, in-depth discussion is required, and “not only one hour but as long as possible. So scheduling sometimes causes difficulties [if] you have different time zones.” Because it was hard to meet face-to-face and wrote something on paper to explain ideas, U.S. professor F felt the lack of in-depth discussion with Korean student B.

5-4-5. Social capital summary

The case of collaborative research between Korea and Tanzania demonstrated that social capital promotes cross-national knowledge sharing and production by interconnecting necessary human and technical resources. In addition, U.S. Professor F argued that the accumulation of social capital expands perspectives of participants who are part of these collaborative projects. He also suggested that time differences in cross-national knowledge sharing and production hinders the accumulation of social capital and reduces the opportunities to exchange ideas among researchers. In short, in a similar vein with economic capital, social capital and the international collaboration is in synergistic relationship. In other words, while social capital shapes cross-national knowledge sharing and production, the latter both influences the social capital and is hindered due to communication constraints. The following section examines how cultural capital is connected to cross-national knowledge sharing and production.

5-5. Cultural Capital

5-5-1. Social norms

Regarding cultural capital, participants in the collaborative project between Tanzania and Korea said that social norms are cultural barriers for collaborating with each other. According to classical sociologists, social norms are informal rules that

govern people's behavior (Parsons 1937; Coleman 1990; Durkheim 2014 [1895]). Tanzanian Local Staff Member K argued that the unspoken rules of Korean and Tanzanian societies often conflict when conducting collaborative projects. The most common example was the speed of work, as both Korean and Tanzanian participants claimed that the working speed of their partners often caused trouble. For Korean participants, the progress of the project was too slow in Tanzania, and for Tanzanian participants, the progress of Korean researchers was too fast. While working on the engineering part, both Korean students and Tanzanian technicians complained that collaboration was difficult, because the expectations regarding the working speed were different in each country.

The difference in working speed resulted from the structural and normative conditions of each country. For example, during my fieldwork, I found that road conditions varied in Tanzania and Korea. When driving a distance of 70 km, it takes more than two hours in Tanzania and one hour in Korea because of unpaved roads and flooding. Furthermore, the electricity and Internet, which accelerate working speed, are more stable in Korea than in Tanzania. While I was conducting field work in Tanzania, the electricity went out for a few minutes or more than an hour almost every day. It was not uncommon for people working on the Tanzanian team to experience electricity outages. In addition, because of the unstable Internet access in rural Tanzania, the joint research team developed an Android app that converts computer data into SMS format and SMS messages into computer signals, and they used text massages for transmitting data from the solar energy monitoring system.[74]

[74]See Wang et al. 2020. "Low-cost far-field wireless electrical load monitoring system applied in an off-grid rural area of Tanzania" *Sustainable Cities and Society*, 59(2020):1-13.

As for the Korean students and Tanzanian technicians, their attitudes toward "working overtime" were different. On the Korean research team, it was natural for students or technicians to work overtime, even if they were not paid, and to finish their project as soon as possible; however, this was not the case for Tanzanian students or technicians. This occurrence is understandable, because work hours in Korea have been longer than in other countries since the 1960s. For instance, the average work hour per worker in 2019 was 1,967 hours, ranking Korea with the third highest average (OECD 2021).

Another typical example was the payment. According to Tanzanian Staff Member K, local people in Tanzania are accustomed to a pre-payment. However, the Korean government, the sponsor of the project, is more used to post-payment based on receipts in the situation of purchasing materials or services such as food catering. For example, during the collaborative project, cultural missteps emerged when the joint research center in Tanzania paid for the food catering for the meeting with local officials, and Tanzanian Staff Member K claimed:

> These local people [who provide the food catering service], they are accustomed to working a certain way. Now [our team is] creating an environment where people think "oh if we work with them, they will pay you after a certain number of days." It's not a good mood. So I tried to call [the providers] and explain. I tried to make it very clear that we would pay earlier if we could. I understand because we are working on a Korea type of situation so it's different. So with these types of situations and rules, at some point, we need to find a way to balance between ours and Korea's for stability.[75]

This passage suggests that the different payment cultures generated an un-welcoming environment for Korean researchers when collaborating with Tanzanian researchers.

[75]Interviewed on June 23, 2018.

Specifically, even if meetings with local officials reduced bureaucratic hurdles, the post-payment system in Korea created an unfavorable situation for the joint research team to organize such meetings. As someone who understands both Korean and Tanzanian cultures, Tanzanian Staff Member K expressed frustration and concern because the disparity in the payment system may affect the sustainability of the joint research project in the future.

In addition to the working speed and payment culture, Tanzanian Professor G highlighted compensation for meetings as another cultural difference between Tanzania and Korea. When I asked about communication problems that occurred during the collaboration, Professor G commented that communication troubles often resulted from cultural differences. Tanzanian Professor G noted:

> Before we start this interview, [you explained that] there is no incentive or payment for this [interview]. Isn't it? I'm used to those things. I know. So it's not a shock to me. But, for a normal Tanzanian, some of those things may be shocking. Okay, you want to use my time, you want to use my technique whatever for free? [In Korea,] if someone invites you to the event to do something [he or she] doesn't expect you to ask for payment. [But in Tanzania, when we are invited, we ask] "If I present there, how much will you pay me? If we go here, how much? In this research, how much?" You see?[76]

Since Professor G had stayed in Korea for his degree, he understood the cultural difference between Tanzania and Korea. Based on his understanding, Professor G tried to minimize the cultural missteps, and he added:

> My advice is, "let everything be clear before they start." Tell [Tanzanian people what] we are going [to do] today. [For instance,] "We have extra time, but we don't have any payment for that. We will pay you for this period of time, but until we finish the work. Are you ready for that?" So get the consent from people. But if they just assume that everyone is

[76]Interviewed on June 27, 2018.

> thinking like Koreans, that's the problem. You know how we work hard in the Korean laboratory. When I was working in Korea, my professor [often] came without any excuse, [saying] we have to finish the work. So I'm used to that spirit of hard work, "fighting." But, [Tanzanian] people are not used to that. So if you want to squeeze someone like that, you have to pay for that. But, [in Korea,] they are not paying for that. For me, it's okay. The good thing for Korean people is that they may not pay you for the work you have done extra. But, they will pay you in a different way. Maybe they will give you another opportunity somewhere. For example, they supported me with the solar power center. That's a lot of money for free. They just help. Someone of this kind, why should I feel stressful because of 50,000 TZS (approximately 20 USD) for a presentation, you know. Sometimes when they invite you to give a presentation, they give 20 USD, if this time they forget and don't give it to me, why should I stress these people who have already helped me a lot? Do you understand what I mean? Yes, but for the locals, this is a big challenge. You can't just use someone's time without compensation.[77]

The compensation for "time and effort" often occurred and hampered the progress of collaborative projects. During my field work, I observed that participants were discouraged from conducting collaborative projects without having aligned cultural capital. Tanzanian Professor G showed that his understanding of Korean culture not only reduces possible conflict but also generates future opportunities. In this case, as his social capital turned into economic capital, his cultural capital was also converted into economic capital.

As implied in the cases of Tanzanian Local Staff K and Professor G, cultural capital is transferable through gatekeepers, who transfer knowledge at interfaces (Cohen and Levinthal 1990). In my case study of the collaborative project between Tanzania and Korea, Staff Member K and Professor G served as gatekeepers. In the process of cross-national knowledge sharing and production, participants resolved conflicts by consulting with gatekeepers who understand cross-national differences.

[77]Interviewed on June 27, 2018

5-5-2. Historical experience

In addition to working speed, payment, and compensation culture, historical experience also created tension between local Tanzanian officials and Korean collaborators. For example, the Tanzania-Korea joint research team had to report their work to the local district office in Tanzania before implementing solar panels and smart-meter systems in a local village. At the meeting with the research team, the local officials assumed that Korean collaborators would sell Korean batteries for the solar panels once the project was over. In other words, the officials did not believe that the project was based on humanitarian aid from Korea to Tanzania. Since they were not engaged from the beginning of the project, the local officials initially believed that Korea had begun the collaborative project with Tanzania to advertise its own products. Accordingly, the officials misunderstood the motivation of the collaborative project. The tension decreased when Korean Local Director D told them that the center uses batteries produced from any country, as long as they perform well and are economical for the Tanzanian local environment. For instance, even though the Korean research team set up the overall solar power system, the team used batteries produced from a German company.[78]

With regard to the assumptions that are unfavorable to Korean collaborators, Tanzanian Local Staff Member K remarked:

> It's very difficult when you are trying to bring something which is from Korea to here because the norms are very different … People sometimes don't want to use something totally different from what they expect. They have a lot of assumptions towards it. I felt those assumptions when we went to the district office. We had district officials questioning our

[78]According to Korean local director D, technologically, it would be good if the joint research team could use Korean batteries. However, D said that Korean batteries are too expensive to use because of the shipping fee.

> motivations. Because [they] don't understand, they think there's conspiracy behind it. You know, that's very difficult. Now I'm in between because I actually know how these [solar panels and smart-meter systems] are going to be helpful, but I should understand how these people feel because of how we've been traditionally raised. That's very difficult, so I'm trying to explain this situation to the Korean staff members and engineers by [saying,] "actually, I understand what Tanzanian officials are saying." But, I also work in the center. I actually understand what we are doing [with the Korean team]. I'm kind of stuck in the middle.[79]

In the interview, by addressing why he should understand how these local officials feel—because he understands how they have been traditionally raised—Tanzanian Staff Member K, who serves as a gate keeper between the Korean team and local officials, asserted that historical experience with outsiders explains the assumption of local officials.

The above interaction with Tanzanian local officials also shows the limited agency of local officials in relation to the social structures of the joint research project between Tanzania and Korea. In the case of this joint research project, the economic capital flowed one way from the Korean government to the Tanzanian local university, and thus local officials were not engaged from the beginning of the project. Local officials not only lacked the social capital related to the human resources participating in the joint research project, but they also lacked the cultural capital relevant to Korea's S&T research collaboration as a means of ODA. However, the joint research project would have encountered administrative difficulties without the involvement of Tanzanian local officials. Hence, the interaction with Tanzanian local officials implies that limited agency under structural discrepancy may lead to the failure of cross-national knowledge sharing and production.

[79]Interviewed on June 23, 2018.

While structural discrepancies hamper such knowledge sharing and production, common historical experience, or shared cultural capital, produces favorable environments for the collaborative projects. For instance, Professor L from a Tanzanian university said:

> We are very happy when we collaborate with countries like Korea, because Koreans remember when they were like us. When your parents were growing up (1960s–70s), it was just like Tanzania. The gap [between Korea and Tanzania] is not as big as, for example, the US and Tanzania. Of course we are collaborating with the US. But none of them remembers when they were like us. It was long time ago. Koreans remember. This is important.[80]

The per capita GDP for Korea was analogous to Tanzania's until 1970, and the per capita GDP gap between the US and Tanzania has significantly increased since then. Therefore, people in their 50s and 60s (my parents' generation) who grew up in Korea experienced the less-developed nation in the 1960s and 1970s. In the above excerpt, Tanzanian Professor L highlights the importance of shared experience and suggests that this cultural experience positions Korea as a unique collaborative partner for Tanzania, which creates a favorable environment for collaboration. This argument echoes the Korean government's claim at the G20 summit and the 2011 High Level Forum on Aid Effectiveness that Korea differs from the existing donors because of its own developmental experience (Kim and Gray 2016).

5-5-3. Cultural differences are everywhere

Regarding cultural difference, U.S. Professor F also illustrated that cultural differences existed in the collaborative project between the US and Korea. When I

[80]Interviewed on June 29, 2018.

asked if he ever felt any cultural difference between Korean Professor A's research team and his team in the US, Professor F explained:

> Cultural difference is everywhere. I do see some cultural differences [between Korean Professor A's and my laboratory]. [For example, Korean Student B] is very diligent working on the Power Point slides, so I suspect she would spend a lot of time each week to prepare the Power Point slides to show professors what she has done this week. I do not ask my students to do such kind of thing every week. I know it could be time-consuming to prepare the Power Point slide itself. But [Student B] has this habit already. [Student B] even had Power Point slides for references. So there are cultural differences.[81]

As for the cultural difference, Professor F focused more on the laboratory-level culture. The Power Point slides that Korean Student B prepared contained the explanation of each week's work, progress from the previous week, work to be done, and references.

With regard to cultural differences in the academic environment, Corley et al. (2017) suggest that cultural dimension affects the productivity of scientific research. According to the authors, scientific outputs, such as career trajectories or research publications of scientists, are influenced by personal-, laboratory-, or disciplinary-level cultural experiences. As for the laboratory culture, the Korean team had its own Power Point template for discussing research. For example, students on the Korean team typically used the template for explaining their research progress to the professor. Since students discussed their individual or group research project at least twice a week with the professor of the Korean team, students spent time organizing their work in the designated format. However, U.S. Professor F considered spending extra time for re-organizing the work as time consuming.

[81]Interviewed on July 21, 2018.

During my field work, I found that the Korean research team had more strict office regulations, such as office hours, duties, and rewards, than the U.S. and Tanzanian teams. For example, students on the Korean team had to come to the office by 9 a.m. and report their attendance to a postdoctoral fellow on the team. This requirement was partly because there were more students working on the Korean team than on the U.S. or Tanzanian team. Strict office regulations, including designated templates, were one of the methods that eased the management of a larger group of graduate students. Even though the U.S. research team did not follow such regulations, Professor F understood Student B's routine as a cultural difference and did not attempt to change it. This implies that the acknowledgement of the cultural differences between laboratories reduces conflicts that may occur during the process of knowledge sharing and production.

5-5-4. Cultural capital summary

As for cultural capital, participants in the joint research project between Tanzania and Korea showed that possessing relevant cultural capital promotes cross-national knowledge sharing and production. Encountering cultural differences often causes disruptions in flows of knowledge, but understanding cultural differences decreases conflicts. In the case of the collaboration with the US, understanding the existence of cultural difference even at the laboratory level helped minimize the negative influence of cultural disparity in the research. By conducting international collaborative projects, U.S. Professor F found that students on the Korean research team are used to re-organizing their work for the laboratory meetings. Even though Professor F did not ask the students to re-organize their work-in-progress for the individual meeting, he understood it as a cultural difference and did not attempt to

change Student B's routine. Laboratory culture differed not only between the US and Korean teams but also between the Tanzanian and Korean teams. For example, while the Korean team required strict office hours, this norm did not exist for the Tanzanian team. In brief, international research collaboration requires cultural understandings at the laboratory level, such as for laboratory regulations, as well as at the national level, such as for administrative procedures. While the previous sections discuss social structures framed by Bourdieu's symbolic powers, the following sections show individual agency found in the fieldwork.

5-6. Normative Science and Agency

The collaborative project between the Korean and U.S. research teams incorporated agency (or personal inspiration) that is closely connected with Merton's normative science. Merton identified the normative values of modern science as universalism, communalism, disinterestedness, and organized skepticism.[82] Since science must be universal, acceptance or denial of scientific knowledge is irrelevant to the personal and social backgrounds of individual scientists (Merton 1942). According to communalism, science must not be kept secret, because scientific knowledge belongs to the community (Merton 1942). As for disinterestedness, Merton (1942: 276) wrote, "A passion for knowledge, idle curiosity, altruistic concern with the benefit to humanity, and a host of other special motives has been attributed to the scientist." Lastly, Merton (1942) suggests that organized skepticism entails that scientific knowledge mandates peer reviews.

[82]In this study, I used the term "communalism" instead of "communism" in order to be consistent with Merton's meaning at the time.

Particularly implied by "universalism," and "disinterestedness," the normative values disconnect social and structural influences on scientific knowledge. Despite critics arguing that the normative values of science are ideal rather than practical, Merton's functional characteristics of science—universalism, communalism, disinterestedness, and organized skepticism—serve as the fundamental guidelines for scientists. When discussing with his students about transferring knowledge from their laboratory to the local village in Tanzania, Korean Professor A argued that there is no reason why technology developed in his laboratory would not work in rural Tanzania. For example, Doctoral Student J on the Korean research team told Professor A that the monitoring system would only work in Korea. Professor A responded, "why not? if [the smart-meter] works here, it must work in Tanzania. It is the same technology."[83] Professor A did not doubt the "universalism" of scientific knowledge related to the development of the energy-monitoring system. Therefore, for him there is no reason why he cannot apply knowledge developed in his laboratory in Korea to a local village in Tanzania.

U.S. Professor F also raised normative values when he explained the advantages of conducting international collaborative projects. Professor F elaborated:

> Advantages [of the collaboration with the Korean research team], there are several. The first one obviously is in this engineering domain some people do modeling. Modeling is computational work. Some people do the experiment. In the best scenario, research needs to be done in both directions. Or come together. I've been working on more computational, theoretical type of work, whereas [Professor A] in Korea mainly focuses on experimental work. So it's a natural, good combination between two disciplines working together. So this is the first advantage of working together to solve bigger problems. People do computational modeling for verifying experimental results. Which means, whenever you do the

[83]Discussed on March 22, 2018.

> model prediction, you predict something you want your model to say is correct. That's called validation.[84]

In this interview, Professor F argued that "validation" is natural for the advancement of knowledge. For Professor F, the combination of hands-on experiments and computational modeling naturally realizes "organized skepticism." In addition, Professor F claimed that research needs to be done internationally for the advancement of knowledge. Considering that being international means the exclusion of social background and openness of scientific knowledge, this argument shows that Professor F believes in both the universalistic and communalistic characteristics of scientific knowledge.

As examined in the previous sections pertaining to structural discrepancies, these normative views of "universalism" and "organized skepticism" are in contrast to the reality of what occurred between the research teams. In the analysis of social structures, structural discrepancies influenced the flow of economic, social, and cultural capitals as well as the cross-national knowledge sharing and production between countries. For example, financial support from the Korean government both initiated and limited the cross-national knowledge sharing and production. In addition, social capital promotes cross-national knowledge sharing and production while time difference reduces the opportunities to exchange ideas among researchers. Cultural capital also both promotes and disrupts cross-national knowledge sharing and production. However, the existence of normative values under structural discrepancies implies the agency of participants. Therefore, the analysis of normative values shows

[84]Interviewed on July 21, 2018.

that agency sustains cross-national knowledge sharing and production under structural discrepancies.

5-7. Personal Will

As for agency, participants in the collaborative project between Tanzania and Korea not only addressed normative values, but also emphasized personal will. While economic, social, and cultural capitals influence behaviors and the minds of participants engaged in joint research projects as well as the knowledge flows and the production that follows, the participants strongly asserted that they willingly engaged in the project. When I asked whether it was his decision to conduct collaborative projects, Korean Professor A said, "Yes, I don't have to do this. As you know, in terms of the journal paper publication, the Tanzanian project is not that helpful for me. But, it is fun. I like conducting this collaborative project."[85] According to Professor A, if he conducted other projects for the same period of time and with the same amount of funding, he could have published more journal articles because the Tanzanian project took a longer time. For Professor A, having fewer publications may be a disadvantage to his career, because the number of publications determines the success and failure of researchers in Korean universities. By stressing that it is optional for him, the professor emphasized his personal will to sustain the project.

Korean Local Staff Member M, an intern who participated in the collaborative project between Tanzania and Korea, also suggested that his personal will was the reason why he joined the project. Staff Member M attended the training for students who applied for internships in developing countries before he flew to Tanzania, and at

[85]Interviewed on April 25, 2018.

the training he heard that the joint research projects are connected to the political benefits of Korea. When I asked his thoughts regarding the connection between national benefits and his decision to join the project, Staff Member said:

> Maybe, I'm not a patriot. What the government does for Korea didn't mean that much to me. Whether the government launches projects for humanitarian reasons or political benefits, I don't care about that much. I was personally curious about appropriate technology and internships in developing countries. I wanted the experience. I wanted to know about what I haven't experienced. When I heard that S&T projects are related to political benefits, I just thought that nothing is free. It wasn't the national benefits that motivated me to join the collaborative project.[86]

As suggested in the above passage, Staff Member M stressed his personal will and agency to join the project. According to him, the reasons why the Korean government initiated international research collaboration with developing countries were not as important as his own reasons to join the project. Staff Member M claimed that his personal interest in the development of appropriate technology in developing countries rather than national interest motivated him to join the internship program of the collaborative projects between Tanzania and Korea.

5-8. Innovativeness

In addition to normative values and personal will, "innovativeness"[87] implies another agency involved in the research collaboration. U.S. Professor F indicated that research must take on the most challenging problems or research questions to advance knowledge. When I asked if he could have done relative research without collaboration with the Korean research team, Professor F said:

[86]Interviewed on July 11, 2018
[87]Herein, "innovativeness" refers novel ideas that advance knowledge.

> I'll say… You could do something similar but not exactly the same. The reason is that [Professor A's] and [Student B's work is] different from all the others. There are some other researchers doing similar work, but not exactly same. That's kind of an important feature of research. You have to do something innovative that no one else is doing. So this innovative project here between us makes some innovative work. Nobody else in the world is doing the same thing. So I'll say from this perspective, it's impossible to work with other people.[88]

As noted in the above passage, Professor F stressed the innovativeness of the collaborative project. He also suggested that collaboration is meaningful, because innovativeness contributes to the advancement of knowledge.

5-9. Public Good

To develop appropriate technologies for rural Tanzania, the Korean and Tanzanian teams involved local knowledge from the village when they implemented the solar power system and smart-meters. According to Jequier and Blanc (1983:10), appropriate technologies have the following characteristics:

- Low investment cost per work-place
- Low capital investment per unit of output
- Organizational simplicity
- High adaptability to a particular social or cultural environment
- Sparing use of natural resources
- Low cost of final product or high potential for employment

As suggested above, limited resources in developing countries led to the development of appropriate technologies. In addition, the appropriateness determines the adaptability of technologies in developing countries.

[88]Interviewed on July 21, 2018.

For the Korean and Tanzanian teams, the involvement of end-users in the local village enabled the development of technologies that are adaptable in rural Tanzania. During the implementation of solar panels and smart-metering systems in a local village of Tanzania, Korean Student N, who participated in the project, said:

> A local staff member taught me that internal switches in our smart-meters are troublesome in a local environment. According to a staff member, technicians must climb up the telephone pole whenever the switches turn down. Before I heard this, I'd never thought about this kind of inconvenience. I removed all the switches in the smart-meters.[89]

Student N suggested that the production of smart-meters for the local Tanzanian village could not have been successful without the knowledge from a local staff member.

The involvement of local villagers was an important feature of the collaborative project between the Korean and Tanzanian teams from the beginning. For example, when the collaborative team decided to provide solar energy and a smart-metering system to the village, the villagers volunteered to build the solar center. The team visited the village and held meetings with the residents before implementing the project. During the meeting, the villagers agreed to actively participate in the project from the beginning to sustain the solar power in the village even after the project ends. Later, when I visited the village with Korean Professor A, social enterprise Director C, and Korean Local Director D, they stressed the importance of involving villagers in the project. For instance, Director C highlighted that the collaborative team members were only temporary visitors in the village and that local villagers are the ones who should manage the solar center. Director C added, "to sustain the solar center even after the project ends, the involvement of village

[89]Interviewed on June 18, 2018.

people from the beginning is crucial." Director C also suggested that villagers feel the ownership of the solar power and relevant technologies by joining the project from the beginning.

In addition to the solar center, the villagers were engaged in the design and installation of the smart-meter. Studies regarding citizen science have suggested that public engagement in science projects raises public understanding of science and improves social well-being (Brossard et al. 2005; Stilgoe et al. 2014; Bonney et al. 2015). In line with arguments from studies pertaining to citizen science, Tanzanian Staff Member K added:

> [Showing village people the smart-meters that we are developing,] we tell people that this is a smart-meter, and this is still in development, meaning many features can be added. I think taking part in developing such [cutting-edge] technology can have a greater impact for local people. It will be very beneficial, because local people [who will use the technology] understand more about [the technology involved in this smart-meter]. Other meters [that villagers didn't take part in the developmental process,] are not anything special, but just a meter.[90]

As shown in the above excerpt, the collaborative team shared their technology pertaining to the smart-meter with the villagers. The team also held a workshop in the village introducing technologies involved in the solar power system. Tanzanian Staff Member K claimed that the engagement of local village people in the process of technology development led to a greater social impact by incorporating ideas from the end-users. Staff Member K said, "People [in the local village] are commenting on what they want. They are like 'Will the smart-meter do this and that?' So they ask, and they liked giving their opinion of what they want. … They were fascinated." Staff Member K suggested that the local villagers were curious about the technology. In

[90]Interviewed on June 23, 2018.

addition, K addressed the convenience and uniqueness of the technology developed in the project when he mentioned the active involvement of local villagers. By incorporating ideas from the end-users, the smart-meter becomes more convenient for villagers. Moreover, since the villagers participated in the project from the beginning, they consider the technology developed in this project to be unique.

5-10. Summary

Economic, social, and cultural capitals influence cross-national knowledge sharing and production. The findings suggest that economic capital initiated the collaborative project and gathered human resources while it also constrained individual activities in the project. At the same time, conducting international research collaboration offered opportunities to expand economic capital. Social capital encouraged cross-national knowledge sharing and production by interconnecting human resources. In addition, the accumulation of social capital broadened the perspectives of the participants who joined the collaborative projects while the time difference hindered the accumulation of social capital. As for cultural capital, understanding cultural differences reduced tensions among participants and encouraged cross-national knowledge-sharing. Moreover, cultural understandings were required not only at a national (macro) level but also at a laboratory (meso) level and at a local (micro) level in the village.

Agency (or personal inspiration) in cross-national knowledge sharing and production is closely associated with the normative values of science, the personal will of participants, the innovativeness of individuals, and the engagement of public knowledge. For instance, participants in the joint research projects naturally raised

universalism, disinterestedness, and organized skepticism when discussing puzzles and advantages of cross-national sharing and production. In addition, participants strongly claimed that they were willingly to engage in the project. Furthermore, the findings show that the innovativeness of cross-national knowledge sharing advances knowledge, and thus it is meaningful. Last, the engagement of the villagers represented another agency involved in the joint project.

The findings in this study complement the weakness of previous studies related to the triple-helix model of research collaboration. In this study, the joint research project between Tanzania and Korea included three actors (universities, governments, and industry), and the university was a leading actor in the process of cross-national knowledge sharing and production. Critics of the triple-helix model suggest that it needs to incorporate other actors such as consumers, users, non-governmental organizations (NGO), and community, and this study demonstrates other actors absent in the triple-helix model, such as economy, social network, culture, and individuals. In addition, Cai and Etzkowitz (2020) assert that interconnecting other social theories to the triple-helix model offers the link between macro- and micro-level actors. This study suggests that Bourdieu's concept of structure and agency not only uncovers actors absent in the triple-helix model but also shows how macro- and micro-level actors are engaged in the process of cross-national knowledge sharing and production.

Previous studies pertaining to barriers of research collaboration have examined structural factors such as high communication costs, transaction costs, and dissimilar bureaucratic system (Landry and Amara 1998; Lee and Bozeman 2005; Ponomariov and Boardman 2010; Kalawong 2016). While reaffirming structural

barriers as suggested in previous studies, this study also showed the role of micro-level actors engaged in the process of cross-national sharing and production. For instance, regardless of the high transaction costs and dissimilar bureaucratic systems between Korea and Tanzania, the personal will of individual participants initiated and sustained the collaborative project.

With regard to Koehn and Obama's (2014) study that addresses unequal relationship between partners in developed and developing countries, this study shows that the unequal relationships result from discrepancies in structural capitals. Accordingly, the analyses of the findings in this study suggest the importance of balancing embedded structure and individual agency in the process of cross-national knowledge sharing and production. The collaborative project in Korea with Tanzania and the US would not have emerged and been sustained without economic, social, and cultural capital as well as individual agency.

In this study, individual agency was the key to overcome the limits resulting from structural discrepancies in cross-national knowledge sharing and production. Thus, to sustain international collaborative projects among countries with various degrees of development, the balance between structure and agency is crucial. The professor in the Tanzanian university implied that the context of transition influenced cross-national sharing and production in Korea by saying "We are very happy when we collaborate with countries like Korea, because Koreans remember when they were like us." As highlighted by this quote, this study shows that actors in a transitioned country contribute to cross-national sharing and production by overcoming structural discrepancies through shared historical experience.

During the fieldwork, my role was not always an observer who was completely detached from ongoing interactions among participants. Some professors, students, technicians, or administrative staff members who either joined one of the collaborative projects or did not engage with any collaborative project asked me what was going on between their research team and the U.S. or Tanzanian teams. This happened because I was familiar with both projects while some professors, students, technicians, and administrative staff members in each research team focused on their own projects. In this case, as Emerson et al. (1995) asserted, I believe my close interaction with people did not disrupt ongoing patterns in the field, because they asked me about collaborative projects that they were not engaged in. Instead, my interaction with people on the research teams increased the intimacy between me and people in my study.

By contrast, in the occasions that I explained what was going on on the other side of the research teams, my presence sometimes directly influenced patterns that were related to structure and agency in the process of sharing and production. For example, during my stay in Tanzania, I helped Tanzanian and Korean participants when they encountered communication troubles. Even though both Tanzanian and Korean participants spoke English, English was not their native language, and this lack of fluency led to miscommunication. Specifically, when there was a meeting with local officials in Tanzania, Korean Local Director D could not understand the question regarding batteries, so I explained to him in Korean that one of the local officials asked him if he or the Korean government would sell Korean batteries after the completion of the project. In this situation, my presence directly bridged the communication between Korean Director D and the Tanzanian local officials and thus

reduced structural barriers. However, my intervention also uncovered the assumptions based on historical experience and the limited agency of the local officials.

As examined in the section about cultural capital, in the process of cross-national sharing and production, participants resolved conflicts by consulting with gatekeepers, who understand cross-national differences. Throughout the fieldwork, my knowledge pertaining to the whole process of joint research projects and English enabled me to serve as a gatekeeper in the process of knowledge sharing and production. In other words, some cultural capital regarding the two joint research projects, three laboratories, three universities, and three countries was transferred back and forth through me during the study. As a gatekeeper, my interaction with participants inevitably affected the relationship between structural promoters or barriers and individual agency. At the same time, my status as a gatekeeper allowed me to access to economic, social, and cultural capital as well as individual agency embedded in the process of cross-national knowledge sharing and production. The following chapter concludes this study by summarizing the previous chapters, addressing the main arguments, and discussing the theoretical contributions and limitations of this study.

CHAPTER 6. CONCLUSION

By highlighting South Korea's transition from a recipient of official development aid (ODA) to a donor country in 2010, this study examined two cases of cross-national knowledge sharing and production in South Korea: one with the US and the other with Tanzania. Previous studies regarding university research collaboration have explored various issues, such as collaborative university-industry-government networks, macro-level and structural factors affecting research collaboration, micro-level and individual factors influencing the collaboration, and the cultural and ethical issues for the various types of collaborations. However, a more in-depth engagement of both structure and agency in cross-national knowledge sharing and production in countries that have recently transitioned from recipients to donors of ODA, such as South Korea, remains an area for fruitful exploration. The examination of case studies of international academic research collaboration projects in South Korea with U.S. and Tanzanian partners in this dissertation fills this gap, shedding new insight into how bridging countries, such as South Korea, negotiate scientific knowledge sharing and production processes. In addition, while the critics of Bourdieu have claimed that he does not sufficiently explain the power of individual will, this study showed the power of individual will under structural discrepancies by using Bourdieu's concepts of symbolic power and habitus.

The objective of this study was to understand the structure-agency relationship in cross-national university research collaboration in a country that has transitioned to a donor of development aid. The analyses of the two collaborative research projects in a Korean university that were conducted with U.S. and Tanzanian universities showed

that actors from a bridge country (Korea) contributed to the cross-national knowledge sharing and production by balancing structural discrepancies through different forms of agency. The findings in this study suggested that economic, social, and cultural capital both promote and hamper cross-national sharing and production among developed, developing, and bridging countries. In addition, while social structure influences behaviors and the minds of participants engaging in joint research projects, individual agency motivated the projects and offered flexibility and opportunities to advance cross-national knowledge sharing and production. This chapter concludes the study with summary, arguments, contributions, limitations, and future studies.

6-1. Summary

Methodologically, this study used qualitative approaches. To avoid overgeneralization, in Chapter 3, I situated the research sites in national contexts by discussing the annual trends of S&T expenditures, GDP, GNI, the tertiary-level school enrollment rate, and bilateral relationships and analyzed an individual interview with Korean Professor A. The statistical data suggested that the three countries—Korea, Tanzania, the US—represent the various levels of development in terms of S&T, economy, and education. The bilateral relationships between Korea and the two other countries initiated with ODA and continuously expanded. In particular, the US-Korea relationship began with U.S. aid to Korea whereas the Tanzania-Korea relationship started with Korean aid to Tanzania. Accompanied by the economic growth of Korea, the US-Korea relationship has changed from unidirectional to bidirectional, and Korea has shifted from a recipient to a donor country of ODA. Moreover, the Korean government has stressed its experience of development to expand the bilateral relationship with Tanzania.

An interview with Korean Professor A, who joined the collaborative research projects with both the US and Tanzania, showed that the merits and demerits of collaboration vary by country. According to the professor, emotional and physical distance as well as educational disparity hinders collaboration with Tanzanian partners while long-term educational goals and personal motivation promote the collaboration. The professor also asserted that the shortage of similar research projects resulting from methodological difference hampers collaboration with U.S. partners even though the collaboration produces research results, such as the publication of journal articles. In addition, the number of Korean students in the US and US students in Korea suggests an uneven relationship between the U.S. and Korean universities.

Chapter 4 examined the history of technology involved in the collaborative research projects. With the U.S. research team, the Korean research team has focused on the advancement of nanoparticle technologies. With the Tanzanian research team, the Korean team has concentrated on the development of solar power systems. While the scientific history of nanoparticles began with the development of quantum mechanics by Max Planck and was then further advanced by other scientists since 1900, the history of solar cells started with the finding of the photovoltaic effect by Edmond Becquerel, and they were subsequently developed by other scientists since 1839. The relevant S&T policies in Korea, the US, and Tanzania suggested that each government has promoted the development of nanoparticle and solar technologies.

In addition to the technological history, Chapter 4 also discussed the emergence of the collaboration with the Korean research team. After explaining three research sites in Korea, the US, and Tanzania, I described how two collaborative projects (the US-Korea and Tanzania-Korea projects) emerged through the Korean

research team. The Korean laboratory consisted of thirty-five people studying in the fields of energy devices, smart robotics, micro- and nano-systems, biomedical devices, and appropriate technologies. The US laboratory was comprised of eleven people studying in the field of new modeling, simulation mechanisms, and multiscale systems. The Tanzanian laboratory consisted of eleven people, including a Korean local director, Tanzanian professors, a director from a social enterprise, and both Tanzanian and Korean staff members. The Tanzanian team worked for the development of new and renewable energy, agriculture, water, education, and business. The collaborative project between the Korean and US laboratories focused on the development of computational models and the production of advanced printing machines through a dual degree program. The joint project between the Korean and Tanzanian laboratories centered on developing, educating, and commercializing innovative appropriate technologies through a joint research center.

Chapter 5 analyzed the findings using Bourdieu's concept of structure and agency. The findings from this study suggested that economic capital not only initiated the collaborative projects and gathered human resources, but it also constrained individual activities in the project. In addition, conducting international research collaboration offered opportunities to expand economic capital. Social capital encouraged cross-national knowledge sharing and production by interconnecting human resources. The accumulation of social capital broadened the perspectives of the participants of the collaborative projects while the time difference hindered the accumulation of social capital. As for cultural capital, understanding cultural differences reduced tensions among participants and encouraged cross-

national knowledge sharing and production. Moreover, cultural understandings were required not only at the macro-level, but also at the meso- and micro-levels.

Agency in cross-national knowledge sharing and production was closely associated with the normative values of science, the personal will of participants, the innovativeness of individuals, and the engagement of public knowledge. For instance, participants in the joint research projects naturally raised universalism, disinterestedness, and organized skepticism when discussing puzzles and advantages of cross-national knowledge sharing and production. In addition, the participants strongly claimed that they willingly engaged in the project. As for the innovativeness, the findings suggested that the uniqueness of cross-national sharing advances knowledge, and thus it is meaningful. Lastly, the engagement of villagers from the beginning of the collaborative project represented another agency involved in the joint project.

6-2. Argument

The detailed analysis of the emergence and development of cross-national research projects identified the relationship between structures and individual agency in the process of cross-national knowledge sharing and production. In particular, the close investigation of the joint research projects, interactions between the research teams, and interviews with the participants contributed to identifying economic, social, and cultural constraints or parameters as well as individual aspirations that shape cross-national knowledge sharing and production. The analyses of the findings regarding economic, social, and cultural capital as well as individual agency showed that structure and agency shape each other in the process of cross-national knowledge

sharing and production. In addition, the findings from this study suggested that agency is crucial for sustaining cross-national sharing and production that occurs under varied social structures.

The findings also indicated that the process of cross-national knowledge sharing and production is habitus that is created through simultaneous interactions of structure and agency. I argue that in this habitus, actors from a bridge country (Korea) contribute to cross-national sharing and production by balancing structural discrepancies through normative values, personal aspirations, individual innovativeness, and flexible thinking. While various economic, social, and cultural capitals influence the behaviors and minds of participants engaging in joint research projects, individual agency motivated the projects and offered flexibility to advance cross-national knowledge sharing and production. As shown in this study, social structures—economic, social, and cultural capitals—not only promote cross-national sharing and production, but they also hamper the collaborative projects. In particular, cultural differences often cause problems for international research collaborations. When social structures hinder international collaboration, agency encourages actors to sustain cross-national knowledge sharing and production.

In addition to the discrepancies in cultural capitals, the analyses of economic and social capitals showed structural discrepancies between the U.S. and Korean teams as well as the Tanzanian and Korean teams. For example, the Tanzanian and Korean teams mainly relied on the funding provided by the Korean government. Despite the participants' acknowledgement of necessity, the Tanzanian government did not offer funding for the joint research project. Thus, the financial flow of the collaborative project between the Tanzanian and Korean teams was unidirectional

from Korea to Tanzania. Nonetheless, the active involvement of local actors from the beginning of the project suggested that the process of knowledge-sharing is bidirectional. That is, the power of individual agency shifted an unequal financial relationship between the two teams and enabled the bidirectional knowledge-sharing. As for the US and the Korean teams, the clear example of the structural discrepancy was the flow of social capital. Students from the Korean university showed more interest in the dual degree program than students of the US university. However, individual agency also shifted this relationship to bidirectional by offering innovativeness in the knowledge-sharing process.

6-3. Contributions

As for the contributions, first, this study showed the essence of balance between embedded structure and individual agency in the process of cross-national knowledge sharing and production. The collaborative project in Korea with Tanzania and the US would not have emerged and been sustained without economic, social, and cultural capital as well as individual agency. As shown in Chapter 3, Korea, Tanzania, and the US have various levels of development. Based on the interview with the professor in the Korean university, Chapter 3 also suggests uneven relationships occur in the knowledge sharing and production among countries with various degrees of development. In this study, while various degrees of developmental status implied the structural disparities of each country, individual agency was the key to overcome the limits resulting from these structural discrepancies in cross-national knowledge sharing and production. Thus, to sustain the international collaborative projects among countries with various degrees of development, the balance between structure and agency is crucial.

Second, this study contributed to advancing the literature regarding cross-national university collaborations and development. The findings in this study suggested that in addition to triple-helix actors (university, government, and industry), structural capital as well as individual agency initiated and sustained the process of cross-national knowledge sharing and production. Bourdieu's frame of structure and agency complemented the weakness of the triple-helix model by engaging other actors such as social networks, regional culture, and individuals and exploring the relationship between macro- and micro-level actors. While reaffirming structural barriers suggested in previous studies, this study implied that the agency of micro-level actors alleviates the barriers. This study also claimed that the unequal relationships between partners in countries with various degrees of development result from discrepancies in structural capitals. Accordingly, the analyses of the findings in this study suggested the importance of balancing embedded structure and individual agency in the process of cross-national knowledge sharing and production.

Last, the case study of researchers in a country that has transitioned from a recipient to a donor country of ODA contributed to scholarship that offers unique insight into successful and effective S&T policies regarding international collaboration among countries with various degrees of development. NSB (2018) suggested that government policies influence S&T collaborations across national boundaries. Through the case of Korea, this study analyzed a unique context of cross-national knowledge sharing and production in a country that has recently transitioned its developmental status. According to Smith and Katz (2000:22), "collaboration does not appear to respond well to top-down policy drivers particularly if they are detached from the pattern of activity on the ground." To put it differently, meaningful collaborations emerge from the individual-level and from within the research process

itself. In accordance with this argument, this study showed that individual agency is an important element for sustaining cross-national knowledge sharing and production between countries with structural discrepancies. Therefore, when designing the relevant S&T policies, the balance between structure and agency must be considered.

6-4. Limitations and Future study

Since this study is limited to only one Korean research team, including more cases involving Korea, developing, and developed countries will provide a better understanding of cross-national collaborative research projects under structural discrepancies. In addition, more case studies of cross-national collaborative projects in Korea will enable cross-case analyses among various countries. For example, Vietnam is another major destination of Korean ODA. Studying the case of ODA projects in Vietnam will show similarities and differences between Tanzanian and the Vietnam ODA projects in Korea. In this study, the cross-national projects with Tanzania and the US were not fully comparable, because the Korean team conducted different projects with the Tanzanian and the US teams. Thus, studying multinational collaborative projects in the future including developed, developing, and transitioned countries will provide more profound comparative analyses. Finally, because of the limited budget and travel restrictions related to COVID-19, I had to focus on the Korean team. To collect more expansive data and to provide less-biased analyses, more field work to assess the Tanzanian and the US research teams will be required for future studies.

APPENDIX

Interview Questions

- What is your collaborative research about?
- How long have you conducted this research collaboration?
- Did you find your research counter-partner?
- How long have you known your research counter-partner?
- What human resources do you share?
- What research materials do you share?
- What other types of resources such as financial resources do you share?
- Who are the financial sponsors of your collaborative research?
- Does amount of or types of financial resources influence for your research collaboration? If so, how does it influence?
- What are advantages and disadvantages of your collaboration? What are the major constraints of the collaboration?
- What is your role in the research project? Do you wish your participation (or role) in the project were different?
- Why do you conduct international collaborative research?
- Have you experienced any difficulty in the collaboration?
- Have you ever studied or worked in foreign countries?
- Do you have any social network that supports or hinders your collaboration?
- Is there any national or institutional culture that support or hinders your collaboration?
- Have any communication problems occurred during your project? Did they affect your project?
- Do the number of collaborators and coauthors influence the success, failure, results, or impact of your research project?
- What are the national and institutional mechanisms (e.g., S&T policies, programs or funding for international collaboration) of international research collaboration and what are the costs and benefits of these mechanisms?
- Do you think there is enough funding for conducting international research collaboration at your institution or in your country?
- Do the regional conditions (e.g., existence of relevant industries or government laboratories) affect your research collaboration?

- In your case, is conducting international, collaborative research helpful in attracting further governmental support of your research? What benefits of international collaboration differ from those of national collaborations?
- What is at stake for your institution to be in this collaboration? Is this collaboration important locally, nationally, internationally?
- Could you have done this work without this collaboration? Did you have a choice?
- For students: where do you plan to use the knowledge you have gained through research in Korea, the US, or Tanzania?

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